Title

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Advanced Public Transportation Systems: A Taxonomy and Commercial Availability

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SUMMARY

Recent advances in electronic technologies may improve transit use and allow greater integration of transit services; new transit technologies may induce people to use transit and improve transit operations. To assess the potential of these technologies, there is a need to systematically explore them.

The main objectives of this study are to:

- Systematically classify new transit technologies and their impacts.
- Use the classification structure for exploring availability of new transit technologies.
- Introduce technology developers to the California Advanced Public Transportation System program.

A structure is developed and applied for investigating the availability of new technologies in the market. The classification structure is based on a conceptualization of how technology attributes and technology performance will impact travelers and operators. After developing a taxonomy for classification of new transit technologies, survey research is used to explore the commercial availability of technologies.

About 100 questionnaires, based on the classification scheme, were sent to technology suppliers--27 responded, including most major Advanced Public Transportation Systems suppliers in the United States. In addition, they mailed useful information about their products.

The survey results showed that technology suppliers have several products which vary in terms of their benefits to transit operators and travelers. For example, in the opinion of technology suppliers automatic vehicles location and identification systems are likely to improve monitoring as well as controlling transit headways, whereas transit and traffic information technologies will have a relatively strong impact on travelers.

Field operational tests of transit technologies, currently underway in California, can benefit

from experimenting with a combination of “smart traveler’ and “smart operator” (including smart vehicle and smart intermodal) technologies. Specifically, certain products may be more promising from the perspective of travelers while others from the perspective of transit operators. The implication for technology testing is that a well balanced set of operator- and traveler-based technologies should be selected. Before testing however, it is important to design a strategy for using various technologies jointly. For example, the joint implementation of a traveler information system and automatic vehicle monitoring system may enhance their individual benefits (compared with implementing them separately). Thus, interaction effects of technologies may be significant and need to be explored.

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CHAPTER 1

INTRODUCTION

While traffic congestion grows, public transit continues to lose market share in the US; for example, the share of transit trips shows a declining trend: 3.6% in 1969, 2.6% in 1983 and 2% in 1990 [31]. One reason for decreasing transit use is the lack of "connectivity" in the present transit system. Greater integration of transit services may be achieved through advances in electronic technologies. To tap the potential of such advances for transit improvement, there is a need to systematically explore available transit technologies. New transit technologies may improve the transit level of service, inducing travelers to use transit. For example, pre-trip planning systems, in-terminal and in-vehicle information systems, and real-time ride share matching systems may attract travelers to transit. In particular, transit improvements may have a significant impact on travel to and from relatively dense activity centers such as downtowns.

In addition to impacting travelers, new technologies may improve transit operations, and consequently reduce (operating) costs. However, the impacts of new transit technologies on individuals and transit operations are not clear. A critical research question is how will travelers respond to the new technologies which make travel by "non-single occupant vehicles" more attractive and how will new technologies impact transit operators? This study explores the availability of new technologies for conventional transit, as well as paratransit, and ride share; it is part of an ongoing effort between Partners for Advanced Transit and Highways (PATH) and California Department of Transportation (Caltrans) to develop the California Advanced Public Transportation System (CAPTS) program. As part of the CAPTS program, several new transit technologies will be tested.

The main objectives of this study are:

- To systematically classify new transit technologies and their impacts. This objective is addressed by developing a taxonomy of transit technologies.

- To use the classification structure for exploring availability of new transit technologies. This is done by developing and implementing a survey of technology suppliers which explores applications and impacts of new technologies on transit operators and travelers. The scope of the survey research work is limited to technology suppliers/developers only. (Transit operators or transit users were not surveyed.)

- To introduce technology developers to the CAPTS program. This objective is addressed by mailing out a CAPTS program along with the surveys.

The unique feature of this study is that a structure is developed and applied for investigating the availability of new technologies in the market.

The next chapter provides a literature review of new technologies and their potential impacts. In Chapter 3 we present the conceptual structure and methodology. The survey results are discussed in Chapter 4. Finally, in Chapter 5, conclusions are drawn and recommendations are given.

CHAPTER 2

REVIEW OF LITERATURE ON NEW TRANSIT TECHNOLOGIES

New transit technologies are being developed in a variety of areas, including traveler information technologies, rideshare matching systems, vehicle monitoring systems, automatic passenger counters, automatic ticketing and payment, on-board computers, automated demand-responsive dispatching systems, transit operations software, and collision avoidance systems, The following sections give a definition of each technology, expected benefits, features and capabilities of new technologies and some current applications of these technologies.

TRAVELER INFORMATION SYSTEMS

Information provided to travelers can be divided into three categories: pre-trip information, in-terminal information, and in-vehicle information. The flow of information should be able to guide travelers through all stages of their journey.

Pre-Trip Information Systems

Pre-trip information refers to information provided to travelers before they start their trips when they have the flexibility of changing modes, routes and departure times. The new technological developments promise enhanced quality and quantity of information provided to the public, enabling travelers to plan their trips.

Pre-trip information offers benefits to travelers. Providing travelers with real-time (and predictive) information on transit services, traffic conditions, parking availability at park-and-ride facilities, etc., may support their travel decisions, increase their confidence in the transit system and reduce their uncertainty about services provided.

Decisions related to trip mode, route, destination, timing, and itinerary may be affected by information concerning transit services, traffic conditions, parking availability, etc. For this reason, pre-trip information can be used to attract travelers. Transit agencies can benefit through increased ridership.

The content of information provided through pre-trip information systems ranges from trip planning to "Yellow Pages" information such as locations of activity centers. A recent study has found an increased need to integrate information on different transportation modes [1]. Table 2.1 gives examples of pre-trip information.

Available Pre-Trip Information Technologies

Manual operation of telephone information centers requires significant costs and may be hindering efficient functioning of transit systems. For instance, the Washington Metropolitan Area Transit Authority (WMATA) telephone information facility lost about 30 to 40 percent of all incoming calls during peak hours due to hang-ups before they replaced their manual system with a computerized system [2].

Many transit agencies, recognizing the importance of pre-trip information system, are using recent technological developments to update their old systems. Pre-trip information is provided through one or more of the following ways: computer-assisted manual information systems, automated telephone information systems, teletext systems, interactive audio/video systems, cable televisions, or personal computers. The following paragraphs explain each technology.

Computer-assisted manual information systems employ a computerized database to assist the operator to answer telephone inquiries [2, 3, 4, 7]. When the operator receives a call, the inquirer is asked about points of origin and destination, day of travel, desired time of travel, etc. After the operator enters the data in the computer, retrieved information is relayed back to the inquirer by the operator. This system allows operators to give information to travelers in a short

Table 2.1 Examples of Pre-Trip Information. (Source [1])

Information thrust on...	Comments and Examples
Route/bus to take	This information can based on traveler selected criteria, such as shortest time, certain itinerary, lowest fare, least walking distance, maximum use of rapid transit
How to get to the bus/train station	(hard copies should be available)
Transfer points (if necessary)	The following information can be provided: - connection point location - waiting time at the transfer station
Departure time, delays, total travel time	- Real-time information is required - Providing departure times for the next 2 or 3 buses is preferable.
Fares and tickets	The following information can be provided: - structure of the fare system - locations to buy the tickets from - accepted method(s) of payment (e.g. credit card or cash) - available discounts - the cost of the ticket
Return trip information	Information on how to return
Traffic conditions	Dynamic information on traffic conditions
Parking availability	Congestion levels at parking lots
Ride-share opportunities	Providing (static/real-time) ride-share information opportunities can be part of transit services.
Ferry services (if available)	
Tourists information	Information on places, events, etc.
Reservation information	Systems may allow advance reservations for trains, hotels, etc.
Services for disabled people	Information on accessibility of various facilities

time compared with pre-computerized systems. The Automated Information Directory System (AIDS) at WMATA, and the Computerized Customer Information System (CCIS) at the Southern California Rapid Transit District (SCRTD), use this method to provide trip itineraries, transfers, and fares information to inquirers [2, 5, 7].

Automated telephone information systems can be divided into: (a) dial phone information systems and (b) voice recognition information systems. In the former, callers have direct access to the information system where telephone inquires are answered by a voice synthesizer [3, 4, 7]. The caller receives information directly from the computer instead of the operator. Options are listed and information about schedules, fares, transfers, and itineraries can be requested by using a touch-tone phone and selecting the desired options. Many systems allow callers to select pre-specified parameters (e.g. shortest walk, lowest fare) to find the best route. A simpler system will assign a unique telephone number to each bus stop that allows the caller to access the route schedule database, and the arrival times of the next two or three buses. In voice recognition information systems, callers do not have to select pre-determined options. Instead, a caller's request is interpreted by the computer system and then digitized. The response from the computer is then relayed to the caller through a voice synthesizer. A demonstration of this system has been done by Metro Dade County Transit in Florida [4].

Teletext systems provide route schedule information to travelers in the form of written text on Cathode Ray Tube (CRT) screens. The textual information is encoded and sent within certain portions of the broadcast signal (called the vertical blanking interval) by a television station. A special decoder built into the CRT set is required to read the transmitted information. Currently, Zenith manufactures two models with such decoders [3]. Such systems will allow travelers to get schedule information on their teletext screens before they start their trips. A demonstration of this technology has been done by the California Department of Transportation (Caltrans) in the Los Angeles downtown area [8].

Interactive *audio/video* ***systems*** are available to travelers in high activity areas such as malls and theaters and transit terminals. The amount of information provided depends upon the information source. Information retrieved from systems that use, for example, a laser disc to store the data differs from information systems that are connected through videotex to a real-time database. The French Teletel, SITU and DIGIPLAN use interactive audio/video systems in high activity locations. Some of these systems also provide a printed itinerary [9]. A system based on interactive voice technologies, offered by Westinghouse Corp., guides a caller through each step with computer-generated, human voice prompts. At each step more details are provided to the caller about his/her inquiry. The system informs the caller about the arrival time of a particular bus [17].

Cable television provides a new medium for traveler information. Organizations which aim to use cable TV to provide real-time transit information include the Ann Arbor Transit Authority [3, 4, 17] and Caltrans is using cable television to transmit a freeway congestion map in Los Angeles. This concept is however, in its early stages of development.

Personal computers (PC) provide another means of disseminating pre-trip information. Individuals can access a transit database using a personal computer and a modem. In the near future, a telephone line might not be necessary to access this information. For example, IBM and Motorola radio network (ARDIS) allow users of portable computers to access databases from anywhere without a telephone line [10].

In-Terminal Information Systems

In-terminal information systems provide a variety of information to travelers at the terminal or bus stop. Information desired by travelers at the terminal can be divided into three separate categories: transit use information, trip-related information, and other information.

Transit use information tells travelers how, when, and where to get information; how to find the desired transit network and route; how to get to the boarding platforms or bus stops; what fare structures and payment methods are available; and how to access these services.

Trip-related information is specific to the trip, i.e., it helps travelers plan their trips in the terminal. It can be information about the current location of the vehicle, disturbances, delays, and actual waiting times. Knowing the exact arrival time of the bus or train helps many travelers take advantage of their waiting time. Surveys conducted in London showed that 95 percent of the underground users found real-time information, such as arrival times and destinations for the next few trains, to be useful [3]. Moreover, providing travelers with real-time information resulted in 16 percent return on London Regional Transport's (LRT) initial investments in the system [3]. The following are examples of trip related information:

- How to get to a specific destination
- What platform/bus to take
- When the next bus will arrive
- Whether the bus/train is running on time
- What is the fare and method of payment
- How long the trip will take
- Whether it is necessary to transfer
- Whether ride-sharing is available at the terminal

"Other information" includes information for tourists, city events, advertisements, and specific transport requests (e.g. access for disabled people, special destinations). Such information can support activity participation decisions of transit users.

Available In-Terminal Technologies

A wide variety of technologies can be used to display in-terminal information. Each has its own advantages and can be chosen to suit particular applications. Flipover displays, matrix displays, Liquid Crystal Displays (LCD), Light Emitting Diodes (LED), plasma screens, Cathode

Ray Tubes (CRT), electro-chemical displays, and TV monitors can be used to disseminate information to travelers at the terminal; furthermore, synthesized voice can be used to provide audio messages. Interactive audio/video terminals have been used to provide trip-related information as well as other information.

Many cities in the U.S. are planning to provide real-time information to travelers at bus stops and transfer stations. The city of Anaheim, California, for example, plans to provide information to passengers at key stops using display boards or smart kiosks. Baltimore Mass Transit Authority (MTA) intends to provide dynamic arrival times of the next three buses at key stops and transfer points. Plans for other cities are also underway [4].

In-terminal displays are relatively widespread in other developed countries. A system called "560" in Ottawa, Canada uses in-terminal displays to provide travelers with arrival times of the next three buses [4, 6]. Ridership was found to have increased 2.8 percent overall and 8.2 percent in the off peak periods in the Ottawa region after the installation of this system [6, 12]. Also, in Nice, France, the VIDEOBUS system at bus stops displays locations of buses along their routes [12]. Other systems, such as PLANIBUS, INFOPLUS, and INFOSTOP, are being used to provide similar information at bus stops in France.

Many French cities have used interactive audio/video terminals to provide trip-related information. The DIGIPLAN system informs travelers about the best route to follow, the best mode of transportation, transfers, walk times/distances, expected journey time, and a hard copy of the plan (if requested). DIGIPLAN uses a touch sensitive screen to input the destination information [11, 13].

Other systems, such as SITU, which is being used in France, allow travelers to choose their own criteria to find the best route. For example, a traveler might select criteria such as least walking distance, maximum use of rapid transit, or lowest fare to find the best route to his/her destination [11, 13].

In-Vehicle Information Systems

In-vehicle information can be provided to individuals while they are traveling in the transit vehicle. The objective of providing this information is to allow access to information while on board. The benefits to travelers include reduction in errors (in unfamiliar areas), and a reduction in travelers' anxiety in case of delays by informing them about the causes for the delays, incidents, and traffic conditions.

Useful information may include a seating plan that informs travelers where to find a suitable empty seat, locations of reserved seats, destination of the bus or train, delays and timeliness information, current vehicle location, distance from destination on a route plan, expected arrival time at key destinations, next stop, transfer points and connection information, current traffic conditions, tourist attractions, news, and advertisements. The type of information provided may account for travelers' desires. However, a survey in Valence showed that one-half of the riders desired operational information (e.g. next stop announcements, information in incidents) while the other half wanted entertainment information (e.g. list of leisure activities, games) [9].

Available In-Vehicle Information Technologies

The technologies used to provide in-vehicle information are as follows.

Matrix displays are used by many vendors (e.g. Luminator) in the US to provide in-vehicle information to travelers.

Synthesized voice messages are used in Madrid Metro where an announcer system provides station and interchange points information automatically. The announcement is triggered by a series of beacons on the track [11].

Video displays are also used to provide in-vehicle information. The MARIA system, developed by Mitsubishi Corporation, uses video displays to provide location, delays, causes of delays, and stop information to travelers [3].

The above systems may be used alone or in combination. In France, systems such as

VISIONBUS, CANALBUS, and TELEBUS, are being used to provide in-vehicle information. Animated graphics is also used in the Visual Communication Network (VCN) system, offered by Telecite Inc., to keep travelers informed on scheduling, current news, cultural events, etc. When this system was used in Montreal, 88% of passengers said that the presence of VCN "enhanced" their trip experience [4].

RIDESHARE MATCHING SOFTWARE

There is a need to expand the flexibility of ridesharing to meet a wider variety of travel requirements, including irregularly-timed commutes, very short commutes, and single-trip travel, all of which are dominated by driving alone [34]. The real-time rideshare system is based upon coordinating the travel of people who are willing to carp001 as passenger and drivers on a trip -by-trip basis [34]. Real-time rideshare matching software permits travelers to have direct access to the traveler information database via touch-tone telephones (audiotex), computer terminals (videotex), personal computers, cable television, interactive television, in-vehicle cellular telephones, hand-held devices, and kiosks [34]. Such real-time matching can provide faster, more convenient, and more sensitive match-ups between individuals and a variety of pre-scheduled or on-demand services.

Some demonstration projects on real-time rideshare matching are envisaged in California and Texas [32, 33]. These studies are in their early design stages and there seem to be no studies on evaluation of rideshare software. The demonstrations are likely to provide useful insights into public acceptance of the real-time rideshare concept.

AUTOMATIC VEHICLE MONITORING SYSTEMS

Automatic Vehicle Location Systems

Transit agencies have depended on regulating officers and assigning dispatchers to keep vehicles on-schedule and to reassign vehicles in case of incidents or high demand for services.

However, this is generally labor intensive, costly, and uncoordinated. Automatic Vehicle Location systems have the potential to reduce such disadvantages. By providing the dispatchers with information about the location, direction, and status of each vehicle, without any action on the part of the vehicles' operators, AVL systems make fleet operations and management more efficient. The use of AVL system can enhance on-time performance, provide planners with a realistic representation of the served streets, and increase customer satisfaction.

AVL systems include a device which locates the vehicle, a computer system which stores and retrieves location information, a communication system which sends data to a control center, and a display system which presents the information to control center personnel [16]. Communication with the control center can be done in the following ways [3]:

- Two-way radios
- On-board cellular telephones linked to modems
- Land mobile satellite communication services

The AVL systems can also be integrated with other systems, such as Automatic Passenger Counters (APCs), Automatic Vehicle Identification (AVI) systems, dispatching software, and traveler information systems. Such integration allows automation of transit operations and may improve the quality of services offered. Moreover, AVL can be used to develop more cost effective demand responsive services.

Location Methods

Different methods have been used to locate vehicles. These methods can be based on dead reckoning, radio frequencies, proximity beacons (sign posts), and satellites. The following paragraphs describe each method.

Dead-Reckoning

Dead-reckoning methods are based on calculating the vehicle's traveled distance and direction from an initial known position (Figure 2.1). The distance measurements are usually made by an odometer, or some mechanism for sensing wheel revolutions. The direction measurements are done by electronic or magnetic compasses. A communication link (such as two-way radio) is used to relay the location information to a control center.

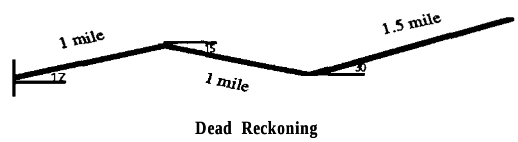

Figure 2.1 Concept of Dead-Reckoning.

Since the computed location depends on all previous location estimates, errors in location accumulate, which can result in large deviations between the real position and the dead-reckoned position. Factors such as tire pressure, road conditions, and side winds can cause these errors. To remove such errors, map augmentation can be combined with dead reckoning [10]. In map augmentation, the route is analyzed as a sequence of vectors of known direction and magnitude. When a match occurs between the traveled vector sequence and the mathematically mapped sequence, the vehicle is located at the mapped location and any accumulated errors from dead-reckoning are removed. Other methods, such as proximity beacons and satellite-based methods, can be combined with dead reckoning to remove accumulated errors.

Radio Frequency Location Methods

Radio frequency location methods locate a vehicle by direct measurements (of time or phase) on radio signals propagating between the vehicle and a number of fixed stations. Such methods have been used in military and commercial applications. The most common are trilateration methods (requiring installation of fixed stations to send and/or receive signals) and methods that utilize existing standard navigation networks, such as Loran C, and Omega network [16].

Circle Trilateration relies on measuring the travel time of the radio frequency from the station to the vehicle and back in order to determine the vehicle's position [16]. This technique requires having two dedicated radio frequency channels or providing the vehicle with a transponder that can rebroadcast the signal at some time increment following the receipt of the incoming signal. Given the radii of at least three circles (Figure 2.2), the vehicle is located at the point of intersection.

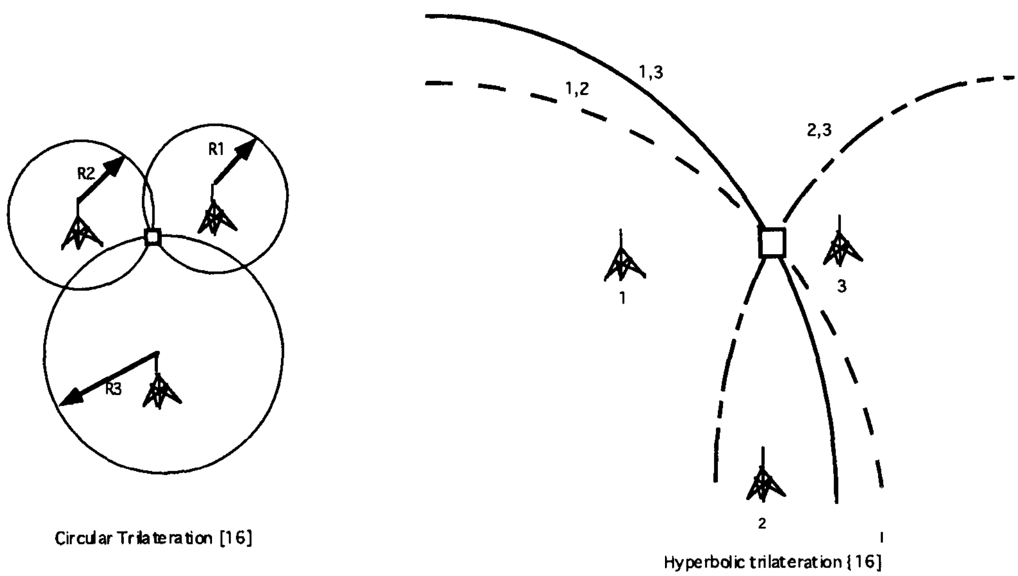

Figure 2.2 Circle Trilateration Method

Another location technique measures the difference between the arrival time of various signals [16]. The time differences define hyperbolas with focal points at the stations. The intersection of the hyperbolas defines the location of the vehicle. This is called Hyperbolic Trilateration (Figure 2.2). Both techniques locate the vehicle at the control center and utilize either phase or pulse ranging for time measurements. Pulse ranging is usually more expensive than phase ranging since it uses short radio frequency rather than conventional frequency modulation. Many of the disadvantages of phase ranging (e.g., interference) can be overcome with pulse ranging. Tall buildings and hills usually disrupt transmitted signals reducing accuracy [18].

A method to utilize standard navigation networks for locating vehicles is based upon signals transmitted from fixed stations instead of from the vehicle [16]. Standard navigation systems, such as Omega, Decca , and Loran C, have used this technique to locate objects [21]. Again, the difference of the arrival time of three signals defines hyperbolic lines, with their intersection representing the location of the vehicle.

Many systems use radio frequency methods to locate vehicles. For example, the Datatrak Automobile Vehicle Location and Reporting System utilizes a network of time synchronized navigation stations to transmit low frequency signals (130 kHz to 300 kHz) on a time shared basis. The location unit measures the phase difference between the signals it received from transmitters within range, and uses this information to generate hyperbolic lines of position. The intersection of at least three hyperbolic lines defines the location of the vehicle within 50 meters [20].

The Teletrac system also utilizes radio frequency to locate vehicles. The system operates on 900 MHz (just below Microwave), and the manufacturer claims that its signals are never affected by congestion or signal distortion. The system is comprised of a PC equipped with Teletrac's mapping software, a modem, and Teletrac's Vehicle Location Unit (VLU). Base stations scattered throughout an area power the communication and location infrastructure. When an inquiry of a vehicle's location is made, a pager activates the VLU in the desired vehicle. The targeted vehicle's VLU then transmits a signal to the base stations, and the location of the vehicle is found by trilateration at the control center.

A computerized bus tracking system based on LORAN-C is being used by the Mass Transit Administration (MTA) in Baltimore, Maryland. The system, supplied by Westinghouse Electric, uses on-board computers to send location and other critical performance data to MTA headquarters every 20 seconds via radio frequency transmitters. Colored displays and two-way voice communications have made the transit operations more efficient. According to MTA the new system improves on-time performance, increases the system's safety, and makes the training of new operators easier [24].

Proximity Beacons Methods

Proximity beacons, also known as signpost systems, use strategically located electronic sign posts that continuously emit location-coded signals to passing vehicles. An on-board system receives and stores the transmitted location code. The stored information is then accessed periodically by a two-way radio to a control center, or decoded by the receiver in the vehicle. The location of the vehicle is then found by determining the nearest sign posts.

Beacon systems can be divided into two systems: "broad" systems that transmit long range signals centered on the beacon, and "sharp" systems that transmit localized signals [3]. This is important when there are overlapping reception areas, where the location is defined by the strongest signal.

Satellite-Based Methods

The ***Navstar Global Positioning System*** (GPS) was developed for real-time, critical, high accuracy applications [19]. The U.S. Department of Defense (DOD) has funded the system to meet the increased demand of navigation and positioning. Civilian access to the system is free, and GPS services have become economically feasible for highway and transit operations. The DOD has downgraded the accuracy of such systems to approximately 100 meters. GPS plans to provide three-dimensional plus-time worldwide coverage; presently, two-dimensional (i.e. latitude and longitude) worldwide coverage is available.

Four satellites are required to fix a position, whereas three may be needed if the altitude is known. In the future, there will be as many as 10 satellites in view of the object to avoid seriously degrading operations in the event of failure of some satellites. Unlike transponder systems, GPS is not saturable and its performance does not degrade as the number of users increases. This is because GPS satellites can continuously emit energy to any number of receivers.

Radio transmission interferences and weather conditions do not affect GPS operations. This property gives GPS an advantage over other systems, such as LORAN-C. However, areas surrounded by tall buildings, tunnels, etc. are unable to receive satellite signals. This is why many systems, (e.g. Magnavox System) are combining GPS with dead-reckoning to ensure continuous monitoring [22].

Radio determination Satellite Services (RDSS) was recently licensed by the Federal Communication Commission (FCC) [10]. The RDSS location method proposed by Geostar company works by sending an inquiry signal via satellite from a ground station. These signals are coded to select specific vehicles for position determination. A transceiver on-board the vehicle receives the signal and responds by sending a signal that carries the vehicle identification code via a minimum of two satellites to the ground station. By comparing the travel time of the transmitted signals and using the position of the two satellites, the position of the vehicle is determined by trilateration. Inquiries on location can be initiated by preset time interval, driver request, transit agency request, etc. RDSS can provide up to 100 million transactions per hour [10].

Although only two satellite-based methods are mentioned in this report, many others are in use. GPS and RDSS are meant to illustrate the concepts.

In addition to using location methods as criteria for evaluation, factors which may be considered in choosing an AVL system are: the data channel from vehicle to the control center, data collection requirements, computation requirements, display requirements, interfaces to other systems, ability to integrate the system with other systems, and desired flexibility with regards to expansion [19]. The federal transit administration is currently funding major AVL demonstrations in Ann Arbor, Chicago, Houston and Baltimore under the umbrella of IVHS.

Automatic Vehicle Identification

Automatic Vehicle Identification (AVI) systems automatically identify vehicles as they pass certain points. AVI offers benefits in many fields, such as fleet management, revenue collection, traffic operations, and safety and law enforcement. In transit operations, AVI systems can be used to identify route number, bus number, driver ID, and other information at a control center. Such information allows control center personnel to track each bus and immediately respond to any problems when identified.

AVI systems comprise three components: a tag/transponder located on-board the vehicle to be identified, an adjacent reading device/interrogator that reads/receives the information from the tag/transponder, and a central computer that stores and processes data.

The identification of vehicles is done in the following manner [26]. Information that identifies a vehicle is encoded onto the transponder or the tag. As a vehicle passes an interrogator/reading device, the interrogator receives coded data from the transponder, or the reading device identifies the vehicle tag. At this point the code is checked for errors before it is transmitted to the central computer for processing and storage.

Some applications of AVI require variable as well as fixed information. For example, in bus fleet control, variable information such as route number, passenger counts, fluid levels, and odometer readings can be entered onto the transponder and automatically read by the interrogator. Assuming a system uses 10 digits of information, five of these digits can be used for variable information and the rest for fixed information [27].

The code structure used by AVI systems can vary from no code at all to the complex structures that permit error correction. However, the use of more elaborate codes increase the initial cost of transponders and interrogators, and the cost of processing the data [27].

The digital capacity of the system is depends upon many factors which include transponder design, interrogator power, vehicle speed, code structure, and the number of readings required for each vehicle passage [27].

Available Technologies

Four major AVI technologies are currently in use:

- Optical and infrared systems
- Inductive loop systems
- Radio Frequency (RF) and microwave systems
- Surface Acoustic Wave (SAW) systems

Optical and Infrared Systems

By the mid 1960's, vehicle identification was achieved using optical technology. These systems require each vehicle to have a unique bar code. The bar code consists of strips of highly reflective material, similar to the material used for highway signs. The tag which contains the bar code is attached to the side of the vehicle or held by the driver. When the vehicle passes the interrogator (a low power laser scanner) the bar code is scanned, analyzed, and converted into a unique digital number.

The emergence of infrared technology resulted in the replacement of optical technology. However, both technologies share some disadvantages, which include the necessity of aligning the tag with the interrogator, the need for having a clean tag at all times and clear weather. Because of these disadvantages, many AVI manufacturers developed other technologies.

Inductive Loop Systems

Inductive loop systems use a loop antenna embedded beneath the surface of the roadway, which communicates with a tag mounted underneath the vehicle. The antenna sends out an interrogation signal and the tag responds by returning a signal modulated according to the data stored in the tag [26]. These systems can be active, semi-active or passive systems, depending upon the source of power used by the transponders [10,281.

In a passive system, the roadway loop generates a power field that induces a voltage in the transponder sufficient to transmit coded vehicle identification information back to the roadway loop. This system is approximately 98 percent accurate. Passive systems are relatively less vulnerable to outside interference and damage [28].

In an active system, the transponder takes its power supply from the vehicle. These systems may transmit an identification code either continuously or only when they are triggered by a signal from the inductive loop in the pavement [10].

In a semi-active system, an internal battery is used to supply power to transmit ID codes when triggered by an inductive loop. No external power supply is needed [10].

Radio Frequency /Microwave Systems

Radio frequency (RF)/microwave systems uniquely identify vehicles. The transponder consists of a small internal receiving antenna, an internal transmitter, and solid state electronic circuitry [26]. In a passive system the interrogator activates the transponder with fixed RF energy. The transponder receiving antenna absorbs some of this energy and converts a portion to a second harmonic frequency, which is transmitted back to the interrogator. The rest of the absorbed energy is used to power electronic circuits. Control logic within the transponder modulates the transmission to the interrogator with the desired identification number [27].

Microwave systems have many advantages over other identification systems. Because they operate at higher transmission frequencies, microwave systems transmit data at higher rates than inductive loop systems. Also, microwave transponders tend to be smaller in size than other inductive loop systems. However, the high power levels required to energize the vehicle-mounted transponders raise concerns about public health and safety [10,281.

Surface Acoustic Wave (SAW) Systems

Surface acoustic wave systems are similar to microwave systems, except the tag consists of an antenna and a lithium crystal which serves as a multi-tapped electronic delay line. The crystal receives an interrogating signal through the attached antenna, stores it long enough to allow other reflected environmental interferences to die out, and then returns a unique phase-coded signal. The lithium crystal has the ability to convert the electromagnetic wave into a surface acoustic wave. SAW tags overcome concerns of high microwave power levels, but are limited to purely fixed-code applications [10,261.

In Europe, AVI used for fleet monitoring purposes has been combined with signal pre-emption measures. For example, in earlier applications of AVI for public transit at Delft, Holland in 197 1, buses were given priority at signals using a simple form of inductive AVI. The system was successful in reducing travel time and delays of buses [3]. However, the study did not seem to investigate the traffic impacts.

When deploying an AVI system, the following factors may be considered: the initial cost, maintenance cost, accuracy and reliability, use of available frequency spectrum, and life of transponders. Other factors, such as difficulty of duplicating the code, resistance to interference, tolerance for environmental conditions, simplicity of tag, and health safety, can also be considered, For a relative comparison of different AVI methods, see Table 2.2 [26]. Widespread application of AVI technologies is expected in the near future. To facilitate toll collection on bridges, California has initiated a standard specification for AVI on toll bridges.

AUTOMATIC PASSENGER COUNTERS

Automatic Passenger Counters (APCs) provide scheduling personnel with necessary data for planning transit operations. Information regarding the maximum load points, distribution of

Table 2.2 Comparison of AVI Technologies [26]

ISSUES \ TECHNOLOGIES	RF/Microwave	SAW	Inductive Loop	Bar Code
Reliability (Accuracy)	HIGH	MEDIUM	HIGH	LOW
Resistance to Duplication	MEDIUM	HIGH	MEDIUM	LOW
Speed of Reading vs. Accuracy	HIGH	HIGH	LOW	LOW
Resistance to Interference	LOW	LOW	HIGH	HIGH
Tolerance to Environment	HIGH	HIGH	MEDIUM	LOW
Simplicity of Tag	LOW	MEDIUM	LOW	HIGH
Health Safety	HIGH	HIGH	HIGH	HIGH

Relative Comparison of AVI Technologies

the load along a route, and total number of passengers served can provide scheduling personnel with information needed to determine the number of vehicles necessary to meet maximum loads and optimal headways between buses. Information on the actual number of passengers on individual buses can allow control centers to reschedule buses to meet unexpected demands. Besides improved service quality, such data provides travelers with information about the status of a transit vehicle (e.g. empty or crowded).

Available Technologies

Many systems have been used to determine the number of passengers boarding or alighting transit vehicles. These include infrared beam systems, pressure sensitive mats, ultrasonic beam systems, multi switch treadle mats, acoustic echo ranging systems [23] and recently smart cards.

Infrared Beam Systems

The infrared beam system consists of two infrared light sources and photo diode detectors placed on one side of the doorway, and reflectors placed on the other side. When a passenger passes through the bus doorway, the light beams sent from infrared light sources are broken down in a unique sequence, depending upon whether the passengers are boarding or alighting, and then transmitted back to their respected sensors by reflectors. Information from sensors is then processed electronically and passenger counts are produced.

Pressure Sensitive Mats

In pressure sensitive mats, strain-sensitive magnetostrictive wire is embedded in standard bus stair treads. When a passenger enters or leaves the bus, the impedance variations of the mat inductance are converted into electrical signals. These signals are then converted to on/off digital signals and used to generate boarding or alighting pulses. The mats are usually placed on the upper and lower steps of a stairwell.

Ultrasonic Beam Systems

The ultrasonic beam system consists of an emitter, a receiver, and a control logic device. The emitter generates a highly directional 50-kHz sound wave. When a passenger boards or alights the vehicle, the receiver detects the interruption of the sound wave. The pulses from the receiver are then fed to a control logic device that provides a signal for each passenger who leaves the bus, and a different signal for each passenger who enters the bus.

Multiswitch Treadle Mats

With multiswitch treadle mats, each switch mat contains 16 ribbon switches oriented parallel to the direction flow. A logic unit accepts the switch inputs from four treadle mats, determines the change in the number of feet per step from the pattern of switch closures, and generates boarding or alighting signal pulses from the patterns of footstep changes. The mats are placed on the upper and lower steps of a stairwell.

Acoustic Echo Ranging Systems

The acoustic echo ranging system passenger counts are determined by the detection and measurement of the transit time of 40-kHz acoustic pulses reflected by passengers that are entering and leaving the bus steps. The direction of motion is then determined through logic circuitry.

Many transit agencies have employed passenger counters. For example, in Ontario, Canada, an infrared beam system is used to collect and transmit passenger count data to a control center via roadside beacons [3]. Along with passenger counts, the system provides time and vehicle location data.

The automatic passenger counter systems may be compared in terms of accuracy and reliability. Infrared beam systems and pressure mats are relatively widely used possibly due to their greater reliability.

AUTOMATIC TICKETING AND PAYMENT

Automation of ticketing and trip payment can benefit both transit operators and riders. It improves transit operations by providing the controllers/managers with data on revenue, passengers, and origins and destinations. This increases the speed of entry and processing of passengers and improves the security of operators and riders due to reduced cash handling. Such automation also reduces the inconveniences of fare payment.

Many vendors are developing ticketing machines that accept different payment methods. For example, the new TVM 5000 machine developed by Schlumberger can accept bills, coins, credit cards, and debit cards. It allows the rider to pay for one ticket or multiple tickets, upgrade his/her ticket, purchase a transfer, or purchase a ticket for an origin other than the location of the TVM [4].

Different methods have been investigated to improve the efficiency of ticketing and fare collection. Payment through credit cards, magnetic cards and smart cards, and automatic passenger identification speeds up passenger entry and processing.

Credit cards can be used to purchase tickets eliminating the need to have change for tickets. And when special readers are installed at gates or fare boxes, credit cards can be used to allow riders to enter and exit rail stations and buses. A demonstration project done by the Merrimack Valley Regional Transportation Authority (MVRTA) in the city of Haverhill, Massachusetts in 1983 , was successful in establishing a credit system and implementing automated collection of charged fares [30]. The project demonstrated the technical feasibility of the post-payment concept.

Smart cards can also improve the efficiency of ticketing and payment. These are plastic cards with a programmable memory chip that can be used for identification, trip payment, and other travel-related functions. Smart cards are being used by the Milton Keynes City Bus in U.K. [3]. The card carries the holders' account balance, which is debited with a discounted fare each time the traveler uses the bus.

Magnetic strip cards that carry the holder's bank account number are used for trip payment in Oldenberg and Lueneburg, Germany. The account number is recorded by a reader unit on-board the bus. Each month the fares due are debited from the traveler's account without exceeding the cost of a monthly pass regardless of the number of journeys [29].

The automatic passenger identification concept can be used for post-payment of a trip. The traveler carries a small microwave or radio frequency tag which is read as the individual enters and exits the transit vehicle. The fares are then calculated and billed to the traveler's account [3].

ON-BOARD COMPUTERS

On-board computers (OBCs) are employed to continually monitor operations of the transit vehicle to reduce the deviations from desired performance. They are used to collect and store data on speed, distance traveled, engine revolutions per minute, oil pressure, water temperature, turn signals on/off, ignition on/off, etc. An analysis of gathered data allows monitoring of vehicle performance and driver behavior.

OBCs consist of a computer attached to a number of sensors. The sensors are linked to different vehicle components and information from the sensors is converted to digital form, which can be stored in either a removable storage module (e.g. cassette tape) or in a recording device inside the OBC that is downloaded at the home-base by connecting a hand-held transfer device or communication cable [10].

SUMMARY

An overview of technologies appropriate for transit was provided. The review indicates that several available technologies can be used for improving and enhancing the performance of transit systems. They offer potential benefits. However, most technologies have not been systematically evaluated in terms of their impacts on travelers and operators. Further, the interactions between various technologies, e.g., joint implementation of traveler information systems and automatic vehicle monitoring systems, have not been explored.

CHAPTER 3

CONCEPTUAL STRUCTURE AND METHODOLOGY

In this chapter the process of technology supply and demand and technology impacts is discussed. Then a structure for evaluation based upon attributes of technologies and their impacts on travelers and transit operators is developed. The structure is used for the design of a survey of technology developers. Then, the methodology elaborates the survey design and implementation.

PROCESS OF TECHNOLOGY SUPPLY AND DEMAND

Figure 3.1 shows the process of technology supply and demand. The demand for technologies may come from the political process, which can encourage the use of certain technologies. For example, the ISTEA legislation encourages multimodal systems because they can reduce traffic congestion and pollution. The demand for technology in transit may also be stimulated by the public (existing and potential users) and citizens' groups (who may advocate transit improvements). Furthermore, the nature and attributes of the technology are likely to influence its demand.

Technology developers and suppliers respond to the market (or create a market) by using advances in electronics to design new transit technologies. After their initial development, technologies may be field (or pilot) tested and deployed. This study explores the availability of newly developed transit technologies for field operational testing. Through such research, Caltrans can assist the public transportation sector with deployment decisions.

The Figure shows that interaction between technology supply and demand results in technology applications. Deployment of transit technologies can have impacts on transit operators,

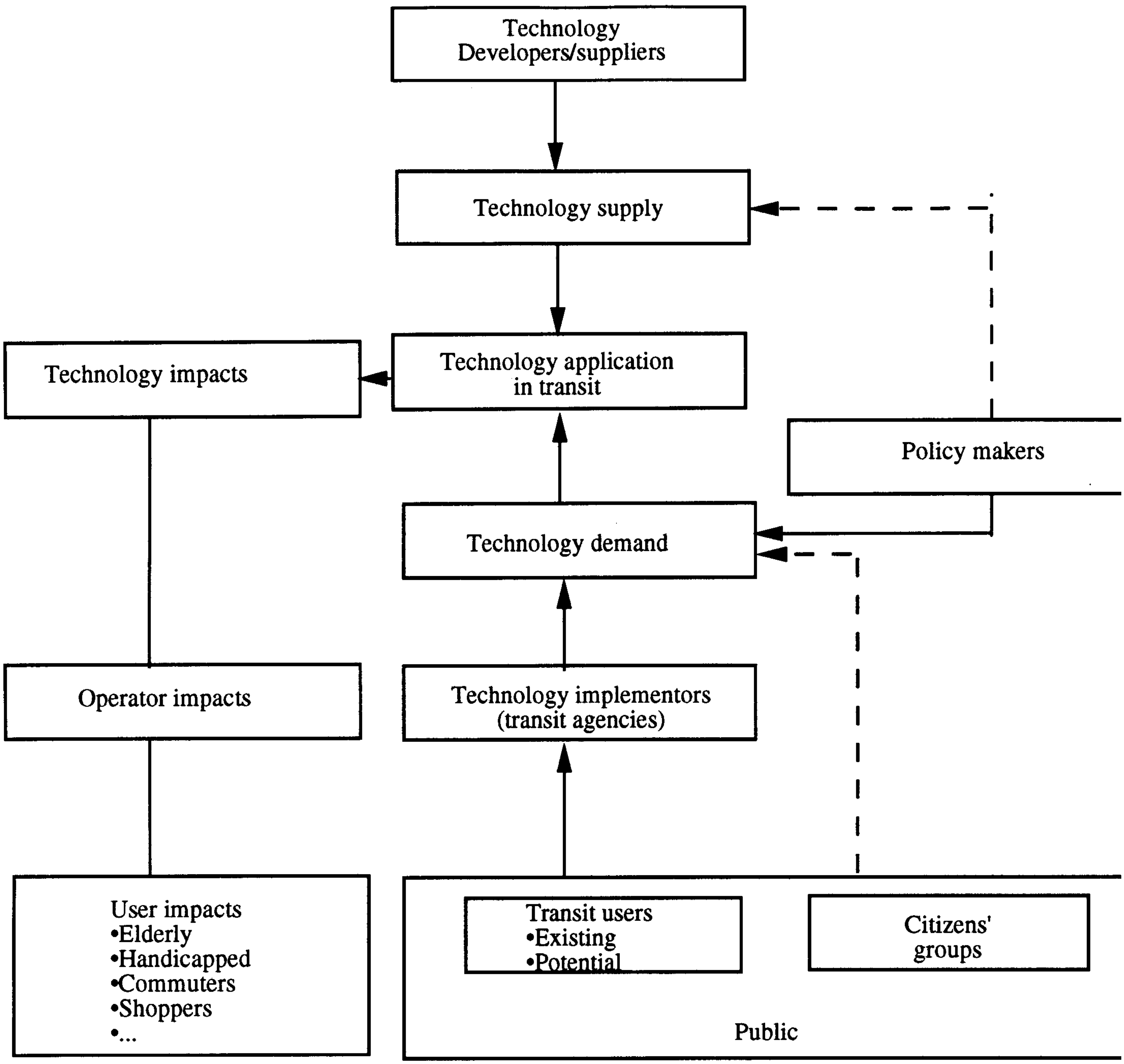

Figure 3.1. The process of technology supply and demand.

transit users (existing and potential), or both. The following (not mutually exclusive) transit operator impacts can be anticipated:

- Reduction in maintenance cost, fuel cost, labor wage, management and marketing
- Improved ability of operator to monitor driver and vehicle performance
- Improved scheduling and dispatching (e.g. ability to control vehicle headways)
- Reduced time required to perform transit operations (or improved productivity)
- Reduced human errors by transit operators
- Increased transit ridership
- Reduced user complaints

The benefits from individual technologies can vary across the benefits space (defined as the areas where benefits may accrue) and depend on technology attributes, among other things. The (transit) user benefits from new technologies may include:

- Travel time savings
- Improved security and (accident) safety
- Increased flexibility in travel choices
- Ease of transit use
- Improved travel comfort and convenience
- Improved satisfaction with transit service
- Improved accessibility

The technologies may impact various groups (such as elderly, handicapped, shoppers and commuters) differently. For example, a technology which enhances ease of transit use may be particularly appealing to the elderly, whereas a technology which increases travel choices may be attractive for shoppers (because it increases shopping locations that they can visit).

To evaluate technologies, a structure can be developed. The "benefits space," can be defined as a continuum ranging from operator-based technologies to traveler-based technologies. The traveler-based technologies are likely to impact traveler behavior more directly compared with operator-based technologies. The operator-based technologies include transit operations software, AVI and AVL systems and the traveler based technologies include various types of traveler information systems. Exactly where to place individual technologies on the continuum is a matter of judgement, however, it is useful to classify them as traveler and operator-based because individual response may vary fundamentally across the two.

TECHNOLOGY FUNCTIONS, TAXONOMIES, AND EVALUATION

Table 3.1 gives a summary of advanced transit technologies in terms of their capabilities, functions, performance, and possible evaluation criteria. It is based on a review of literature and our judgement. The information presented in the table formed the basis for survey research. An example is given to elucidate this. Pre-trip information systems can disseminate information by several means, including telephone, computer, and television. They provide historical and real-time information on transit operations and schedules to support traveler decisions. Some systems may also provide advance ticketing and reservation. Pre-trip information technologies can be assessed based upon their presentation quality, the nature and accuracy of information provided, and traveler benefits such as travel time savings.

Table 3.2 shows a taxonomy of benefits. It is expected that "smart traveler" technologies will be rated highly in terms of measures of performance, e.g., information systems are more likely to improve comfort and traveler satisfaction. The following paragraphs develop classifications for various traveler- and "smart operator" technologies. These taxonomies of technologies will help in:

- Selecting the appropriate technologies for operational testing

Table 3.1. Characteristics of advanced public transportation technologies

Technology	Technology Base	Technology Capabilities/ Functions	Technology Performance/Evaluation
Pre-Trip Information Systems	*Auto dial phone *Telephone to computer operator •Voice recognition •Computer & modem *Teletext *Videotext •Cable TV •Audiotext •Interactive voice response *Interactive television	*Provides historical or real time information on: -Schedule/departure times -Multi-modal itinerary -Trip chaining (itinerary optimization) -Ride share opportunities -Best route based on traveler criteria: Shortest time Lowest fare Intermediate stops Maximum use of rapid transit Least walking distance -Connection points -Transit vehicle location •Provides advance ticketing & reservation	*Presentation quality *Accuracy of information content, format, and nature of information *Relevance and timeliness of information to traveler decisions •User benefits (travel time savings) *System management benefits
In-terminal Information Systems	Disseminates info using: •Dot matrix displ. •Flipover displ. •LCD •TV monitors *Synthesized voice messages *Audio terminals *Video terminals w/keypads w/touch screens	*Provides historical or real time information on: -Schedule/departure times -Multi-modal itinerary -Trip chaining (itinerary optimization) -Ride share opportunities -Best route based on traveler criteria: Shortest time Lowest fare Intermediate stops Maximum use of rapid transit Least walking distance -Connection points -Transit vehicle location/delays information -Terminal related information (e.g., layout) -Destination •Provides advance ticketing & reservation •Can be linked to other sources of info	*Accuracy of information •Content, format, and nature of information ● Relevance and timeliness of information to traveler decisions •Presentation quality *User benefits

Technology	Technology Base	Technology Capabilities/ Functions	Technology Performance/Evaluation
In-vehicle Information Systems	Disseminates info: *Synthesized voice messages *Dot matrix displ. •Video displays •Flap displays *Heads-up display	*Provides historical or real time information on: -Schedule -Expected next stop arrival time -Waiting times at connecting points -Connecting services -Destination -Seating availability -Next stop announcements *Provides advance ticketing & reservation *Route guidance and navigation	*Accuracy of information content, format, and nature of information *Relevance and timeliness of information to traveler decisions *Presentation quality *User benefits *System management benefits
Ride Share Matching Software	Platform Operating system Map base Interface -Telephone -Computer -Facsimile -Teletext/Videotext	*Provides real-time matching *System matches passengers by -Grid -Zip code -Street address or landmark - Other criteria	*Successful matches *User benefits (less wait time, increased flexibility, greater convenience)
Automatic Vehicle Identification Svstems	Infrared/Optical Inductive Loop Radio Frequency Surface Acoustic Wave	•Can provide two-way communication *Encodes variable data	*Percentage of vehicles missed *Operator benefits (eg, headway control)
Automatic Vehicle Location Systems	Dead Reckoning GPS Proximity Beacon Radio Determination	*Tracks location of vehicles, uses various location methods	*Tracking accuracy *Frequency of information updates *Improvement in operations
Collision Avoidance Systems	Radar Infrared laser Sonar	*Software may provide: -warning only -Warning and braking	*Safety (false positives, false negatives) *User benefits (e.g., keeps drivers alert)

Technology	Technology Base	Technology Capabilities/ Functions	Technology Performance/Evaluation
On-Board Computers	Platform Operating system Map base	*System collects: -Speedometer data -Ignition status (on/off), oil, temperature ● OBC can be connected to a central computer for data gathering and processing	*Accuracy of data *Operator benefits
Transit Operations Software	Platform Operating system Map base	*Supports historical or real time: -Marketing -Management & administration -Network & operations planning -Vehicle & crew scheduling *Software connected to: -Automatic vehicle location (AVL) -Automatic vehicle identification (AVI)	*Operator benefits (marketing, management, planning)
Electronic Ticketing Systems	Info collection: -Origin destination data -Revenue information disaggregated by route and/or ticket type -Passenger information disaggregated by class, route, time of day	•Accepts credit cards *Tickets may be reused by adding fare to them *Tickets good for one, limited, unlimited ride(s) *Tickets can be used for multi-modal transport	*User benefits (convenience, time savings)
Automatic Passenger Counters	Counting Device: *Pressure-Sensitive Mat *Infrared Beams *Treadle mat *Smart card Info stored on: •RAM *Magnetic tape •Compact disk	Sends passenger counts at vehicle stops to the dispatcher in real time. Data can be processed into: *Total number of passengers served along route *Number of passengers on the bus *Number of passengers boarding and alighting at certain stops	*Percentage of passengers the system misses *Operator benefits (improvement in dispatch operations/planning)

Technology	Technology Base	Technology Capabilities/ Functions	Technology Performance/Evaluation
Automated Demand-Responsive Dispatching Systems	Platform Operating system Map base	*Supports historical or real time: -Scheduling -Dispatching -Billing -Service monitoring & reporting considers traveler preferences *Provides transit vehicle location to traveler in real time, best route using traveler criteria, and advance reservations *Responds to immediate requests and standing orders	*Operator benefits (improved scheduling, dispatching...) *User benefits (convenience, flexibility...)

Table 3.1 Taxonomy of transit technology impacts.

Technology	Improved Monitoring	Controls Transit Headways	Reduced Labor Hours	Reduced Operating Time	Reduced Human Error	Improved Security	Reduced User Complaints	Improved Safety	Increased Travel Flexibility	Easier To Use Transit	Improved Travel Comfort	Improved User Satisfaction
Pre-Trip Information Systems												
In-Terminal Info Systems												
In-Vehicle Info Systems												
Rideshare Matching Software												
Automatic Vehicle Identification												
Automatic Vehicle Location												
Collision Avoidance Systems												
On-Board Computers												
Transit Operations Software												
Electronic Ticketing Systems												
Automatic Passenger Counter												
Automatic Dispatch Systems												

- Modeling or optimizing transit system performance and designing surveys to understand traveler response
- Evaluating the impacts of technologies

Traveler Information Systems

Information technologies can influence various traveler choices, and they can be classified according to their impacts on traveler decisions. The basic idea of ATIS technology classification is that the type of information influences travel choices. Information can be either static or dynamic, Static information related to travel choices does not change with time, whereas dynamic information related to travel choices changes with time. Information can be further subdivided into qualitative or quantitative. Qualitative information is non-numerical (it does not include estimates of parameters such as expected arrival time to destination and number of available seats on board), whereas quantitative information is numerical (it includes estimates of parameters). Information type and travel choices form a two dimensional taxonomy matrix (Figure 3.2). To illustrate this matrix we give examples for some of its cells:

- ***Static Qualitative, Multimodal Information (Cell "A").*** Static information about availability of trip connections may support multimodal choice. For example, based on trip connections information, a traveler may use the bus as opposed to their car to reach the nearest train station.
- ***Static Quantitative, Multimodal Information (Cell "B").*** Static information about transit schedules may support the choice of modes.
- ***Dynamic Qualitative, Multimodal Information (Cell "C").*** Real-time information about whether or not a bus is on-time may support the choice of using a bus or walking to a train station.
- ***Dynamic Quantitative, Multimodal Information (Cell "D").*** Real-time information about

TECHNOLOGY : ______________________________

MANUFACTURER/SPONSOR: ______________________________

INFORMATION TYPE / CHOICES	STATIC		DYNAMIC	
	QUALITATIVE	QUANTITATIVE	**QUALITATIVE**	**QUANTITATIVE**
DESTINATION				
MULTIMODAL	A	B	C	D
DEPARTURE TIME				
ROUTE				
PARKANDRIDE				
TRIP CHAINING				

FEATURES :

☐ PORTABLE ☐ NON-PORTABLE

☐ IN-VEHICLE ☐ OUT-OF-VEHICLE

☐ AUDIO cl VISUAL

MULTIMODAL RESERVATION c l **YES** ☐ **NO**

INTEGRATED BILLING SYSTEM ☐ **YES** c l **NO**

SEATING AVAILABILITY ☐ **YES** c l **NO**

VEHICLE LOCATION ☐ KNOWN ☐ UNKNOWN

NUMBER OF VEHICLES USED IN THE TEST: ______________

TECHNOLOGY STATUS: ______________________________

Figure 3.2 taxonomy of advanced transit information technologies expected arrival times of the next bus or train can support the mode choice.

The taxonomy illustrates features of the transit information technologies which may benefit travelers, e.g., time savings by integrated billing service and adding trip convenience by multimodal (park-and-ride) trip reservations. In addition to dynamic information, the systems may provide predictive information, such as the expected time from recovery of a transit system breakdown.

Ideas generated by the taxonomy matrix and technology features were used in the survey of the transit information technologies. The taxonomy helped frame the evaluation of different advanced transit information technologies.

Rideshare Systems Technologies

Real-time rideshare matching systems allow trip makers to call in for sharing a ride either as drivers or as passengers. Rideshare matching software allows travelers to review rideshare options, identify individuals whose needs closely match their own and reserve the trip in advance. Rideshare systems will provide information to travelers and, as such, are a part of ATIS. The taxonomy matrix can be used to understand how traveler decisions may be influenced by real-time rideshare information. The following information can be provided by a rideshare information service (for high occupancy vehicles):

- ***Static-Qualitative Information.*** Examples of static-qualitative information are potential candidates for rideshare, location of candidates' homes and their preferences.
- ***Static-Quantitative Information.*** Examples of static-quantitative information are preferred times of departure for the candidates and distance to homes of the candidates.
- ***Dynamic-Qualitative Information.*** The rideshare system may offer the opportunity to inform customers of delays due to emergencies.

- ***Dynamic-Quantitative Information.*** The service may give information on the number of persons available at certain times of the day, expected length of delays, and travel time information for HOV lanes.

Automatic Vehicle Control System Technologies

Early versions of Automatic Vehicle Control System technologies provide driver warning and assistance, resulting in collision avoidance. The technologies can perform collision avoidance by obstacle detection, lane edge warning, and lateral/longitudinal control. These systems are in their early stages of development; they use radar, infra-red laser or sonar and provide either warning only or warning and braking. They can improve safety by reducing accidents. The information that is provided to drivers is dynamic. It can be qualitative, such as “you are very close to the right edge of the lane,” or quantitative, such as “you are x feet away from the vehicle in the right lane.” The type and format of information will have a significant effect on the reaction of the driver.

Automatic Vehicle Monitoring, Automatic Passenger Counters, Automatic Ticketing and On-Board Computer Systems

Certain technologies serve as the “eyes and ears” of the transit agency; they improve transit operations, while increasing the comfort and convenience of the journey for travelers. For example, electronic ticketing systems automate fare collection, adding convenience and some travel time savings to a trip. In addition, they provide valuable data to transit operators for planning and marketing research. Another example is the APC system which sends passenger counts to a central system in real-time. This information can be processed for making dispatching decisions and stored for use in operational planning and scheduling. Note that improvements in transit operations can sometimes translate into individual level benefits such as increased comfort and convenience, and travel time savings.

The taxonomy of technologies can also be applied to the incoming data from various technology sources. The decisions to be supported in this case are operations, dispatching, scheduling, planning, and marketing (Figure 3.3). The content of incoming data and processing/analysis techniques are likely to influence operator decisions. The incoming data can be historical (qualitative or quantitative) or real-time (qualitative or quantitative). The data can be related to ***system performance***, which includes transit system performance, traffic system performance, and traveler information system performance, as well as ***traveler behavior*** including origins and destinations. The attributes of incoming data such as accuracy and validity are important, i.e., accurate data are likely to provide stronger decision support. On-board computers collect vehicle data (oil, water, engine temperature, vehicle speed, signals, etc.) which can be used by the driver and transit operators to monitor vehicle performance and respond quickly to breakdowns. Further, AVI and AVL systems provide useful information for monitoring the progress of vehicles. This information can be used to improve operations, e.g., real-time adjustment of vehicle headways. Transit operations software supports transit decisions by performing planning, vehicle and crew scheduling, marketing, management, and maintenance. The software can be connected to AWAVL systems for greater integration.

METHODOLOGY

The methodology for this study is illustrated in Figure 3.4. The APTS technologies were classified and their (commercial) availability was explored by surveying technology suppliers. The conceptual framework developed for transit technologies suggests that they can be placed on a continuum according to their impacts on traveler decisions and transit operations.

The survey design is based on technology factors which include technology base (or type), capabilities and functions, and performance characteristics. The survey also inquires about the nature of transit technologies, their implementation in transit agencies, their impacts on travelers and transit operations and attributes of the technology suppliers (See Appendix 1 for the survey

TECHNOLOGY : ______________________________

MANUFACTURER/SPONSOR: ______________________________

DATA CONTENT / ACTIONS	STATIC		DYNAMIC	
	QUALITATIVE	**QUANTITATIVE**	**QUALITATIVE**	**QUANTITATIVE**
OPERATIONS				
DISPATCHING				
SCHEDULING				
PLANNING				
MARKETING				
OTHER				

TYPE OF DATA:

☐ TRANSIT SYSTEM PERFORMANCE0 TRAFFIC SYSTEM PERFORMANCE

☐ TRAVELER INFO SYSTEM PERF. ☐ TRAVELER RESPONSE AND BEHAVIOR

ATTRIBUTES OF DATA:

☐ ACCURACY ☐ VALIDITY

☐ CONTENT ☐ FORMAT

TECEINOLOGY STATUS: ______________________

Figure 3.3 Taxonomy of advanced transit technologies.

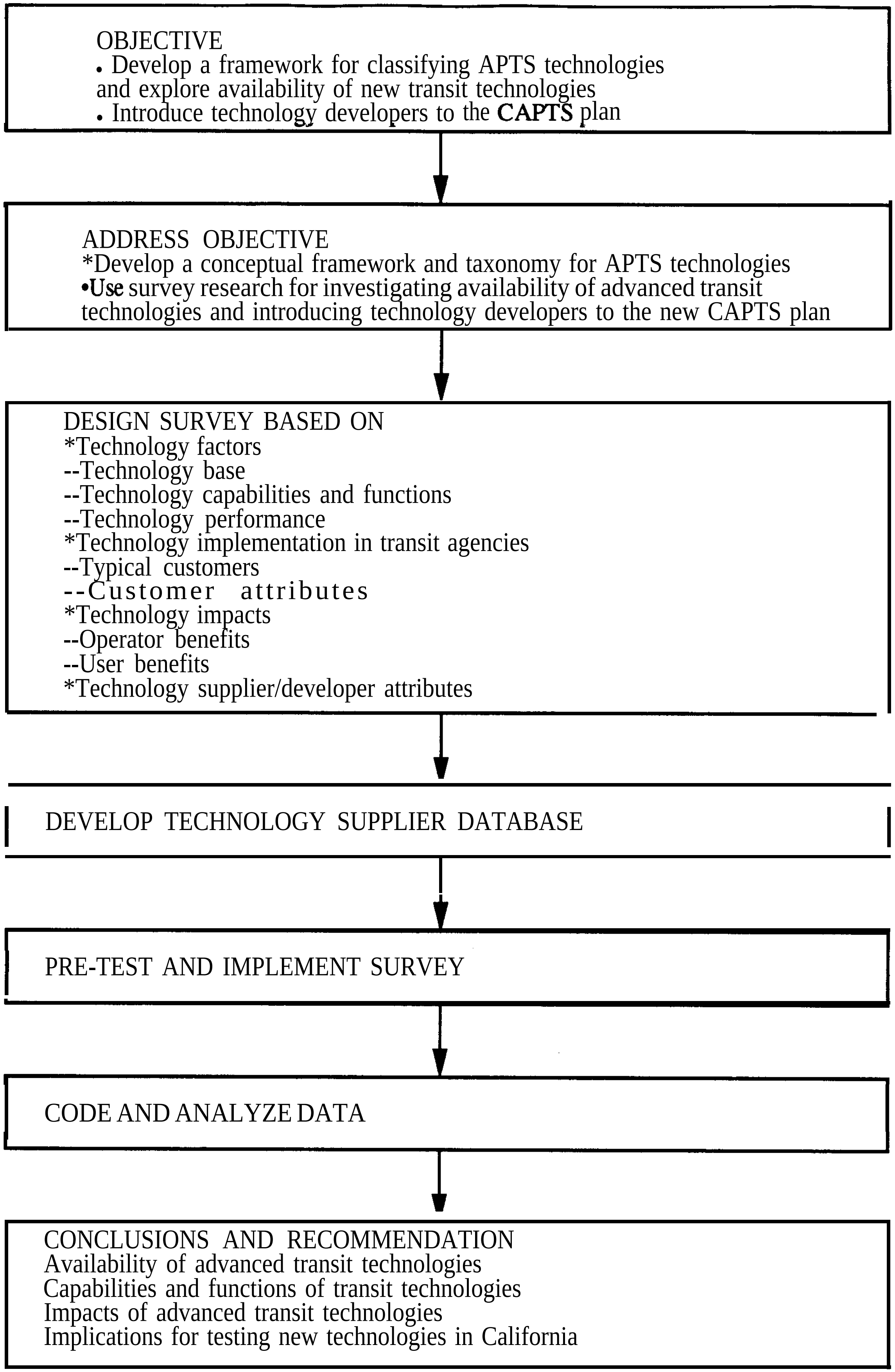

Figure 3.4. Structure for the study.

instrument and cover letter).

The survey instrument was pre-tested by mailing it to 10 technology suppliers. It was revised based on 6 responses. The refinements pertained to:

- Clarifying the questions regarding impacts on transit travelers and operators
- Rewording some questions because either they did not convey the intended meaning or they were too long
- Changing the sequence of some sections and deleting some questions to improve response rates

After pretesting, the surveys were mailed out to a total of 95 local and international transit technology suppliers. The mailing lists were obtained from data on transit technology vendors.

Accompanying the questionnaire was a CAPTS program developed jointly by Caltrans' Office of New Technologies and PATH (see Appendix 2). Inclusion of this plan was expected to increase the awareness of CAPTS among technology suppliers. Judging from the responses, technology developers seemed enthusiastic about CAPTS; they sent us brochures about their technologies (see attached) and expressed interest in participating in field operational tests. In all, twenty seven technology suppliers (28.4%) responded. However, not all companies supplied the technologies we asked for, nor did all of them fill out the questionnaire reducing the effective sample size to about 20 respondents. The responses received were clear. Appendix 3 provides a list of companies who responded. They were strongly biased toward local (US) technology suppliers.

Due to a low response rate, telephone follow-up calls were made. However, that did not increase the response rate significantly. We found that 14 suppliers (14.7%) were either no longer in business or could no longer be located. Despite our follow-up efforts, 54 suppliers (56.8%) did not respond--even though they were sent another copy of the questionnaire.

The responses were checked for logical errors and coded. Then the data were analyzed and conclusions were drawn.

CHAPTER 4

RESULTS

In this chapter we present the results from survey research on the commercial availability of advanced transit technologies. The survey of technology suppliers was structured as follows:

- Available technologies in terms of capabilities and functions.
- Technology performance in terms of evaluation criteria.
- Technology implementation in transit agencies ("typical customers" and customer attributes).
- Impacts of technologies on operators and travelers.
- Technology supplier attributes.

The following sections present the survey responses and a discussion of the findings.

ANALYSIS OF SURVEY RESPONSES

Responses were spread evenly across technology categories (Table 4.1). This is encouraging and indicates that all of the technologies we inquired about are commercially available for field testing.

A respondent profile is shown in Table 4.2. There is a large variance among technology suppliers in terms of years in business and number of employees. Both small and large companies are competing in the transit technology market. A majority of the respondents manufacture their products in the United States (82%) and 93% fabricate their products in-house; 72% have offices in California.

Table 4.1 Summary of responses for various technologies (N=20)

Technology	Number of Suppliers
Pre-Trip Information Systems	10 (50%)
In-Terminal Information Systems	7 (35%)
In-Vehicle Traveler Info Systems	6 (30%)
Ride share Matching Software	5 (25%)
Automatic Vehicle Identification	6 (26%)
Automatic Vehicle Location	10 (50%)
Collision Avoidance Systems	2 (10%)
On-Board Computers	7 (35%)
Transit Operations Software	3 (15%)
Electronic Ticketing Systems	2 (10%)
Automatic Passenger Counter	3 (15%)
Automated Dispatching Systems	6 (30%)
Other Systems	7 (35%)

Table 4.2 Respondent profile.

Respondent Attributes	Number of Suppliers
Number of Years In Business:	
Up to 5	4
6-10	4
11-15	2
16-20	4
21 or more	1
(Average = 2 1.4 years)	
Number of Full-Time Employees:	
up to 10	4
10-100	2
101-200	3
201-300	4
More than 300	3
(Average = 228 employees)	
Number of Engineers/Programmers:	
up to 10	5
10-100	5
More than 100	5
(Average = 85)	
Suppliers With In-House Manufacturing:	14 (82%)
Suppliers With Business Offices in California:	18 (72%)
In-House Fabrication:	15 (93%)

The respondents analyzed traveler and operator impacts of their highest revenue technology sold to a "typical customer." Table 4.3 shows that the suppliers were evenly distributed across various technologies. Table 4.4 shows a taxonomy of technology benefits for the highest revenue technologies, from the suppliers' perspective. The taxonomy matrix provides a general framework for analyzing benefits. The subjective technology evaluation (opinions) provided by the respondents are likely to be biased because they are selling these products. Also, the sample size is small, so the results are not generalizable. Yet the responses provide some insights into the "relative" impacts across the categories. The AVL system is rated highly on improving monitoring as well as controlling transit headways, as expected. The responses indicate that on-board computers will improve monitoring, reduce human errors and possibly improve safety. Furthermore, suppliers believe that information technologies will have a relatively strong impact on travelers in terms of increased comfort and satisfaction, as expected.

Pre-trip Information Systems

Fifty percent of the companies sell pre-trip information systems (10/20). They are: Schlumberger Technologies, Tidewater Inc, Etak Inc, Qualcomm Inc, Megadyne Info Systems, Fone Link Inc, Commuter Transportation Services, Teleride Sage Ltd., Westinghouse, and Peek Traffic. Among the available systems, five use automatic dial phone technology (5/10), six use telephone to computer operator technology, two use telephone and voice recognition technology, five use computer modem technology, seven use teletext, four use videotext, one uses cable TV, and four systems use other kinds of technology. In terms of information provided to the traveler, 90% (9/10) have systems that provide schedule/departure times (30% are based on historical information and 70% are real time); 70% provide multi-modal itinerary information (50% have historical information and 50% have real time information); 70% provide trip chaining (itinerary optimization) information (42% historical and 57% real time); 60% provide information on rideshare opportunities (66% historical and 33% real time). Further, the systems can provide best

Table 4.3 Largest revenue technologies for various suppliers.

Technology	Suppliers' Largest Revenue Technology	Suppliers' Second Largest Revenue Technology
Pre-Trip Info Systems	11% (2)	27% (3)
In-Vehicle Traveler Information	5% (1)	
Ride Share Matching	5% (1)	27% (3)
Automatic Vehicle Identification	17% (3)	
Automatic Vehicle Location	17% (3)	9% (1)
On-Board Computers	5% (1)	9% (1)
Transit Operations Software	5% (1)	
Electronic Ticketing System	5% (1)	
Automatic Passenger Counter	5% (1)	
Automated Dispatching		18% (2)
Other transit technologies	22% (4)	9% (1)

Table 4.4 Opinions of technology suppliers regarding the main transit product.

Technology	Improved Monitoring	Controls Transit Headways	Reduced Labor Hours	Reduced Operating Time	Reduced Human Error	Improved Security	Reduced User Complaints	Improved Safety	Increased Travel Flexibility	Easier To Use Transit	Improved Travel Comfort	Improved User Satisfaction
AVI	3	3	3.33	3	3.66	3	2.33	3.33	3	3.33	3.66	3.66
AVL	3.66	3.66	3	2.66	3	3	3	2.33	2.66	2.66	2.66	3.33
OBC	4	2	2	2	4	3	2	4	2	2	2	2
Dispatch						-	-					
CAS												
APC	2	2	3	3	3	2	3	2	2	2	2	2
PTI	2	2.5	3.5	3.5	3.5	2	3.5	2	3.5	4	2.5	3.5
ITI	-											
IVI	2	2		4	4	3	3	2	3	4	4	4
Rideshare	4	4	4	4	4	2	4	2	4	4	2	4
Software	4	4	4	4	4	2	4	2	2	2	2	4
ETS	-		3	3	4	4	3			3	3	4
Other	4	3.5	3.75	3.5	4	3	3.33	3.33	3	3.5	4	4

Averages are taken from responses by suppliers of the transit technologies.
The possible responses are 0) Strongly disagree 1) Disagree, 2) Neutral, 3) Agree, 4) Strongly agree.

route information based on traveler selected criteria, which include: (i) shortest time--60% of the suppliers (40% historical and 60% real time), (ii) lowest fare--60%, (iii) intermediate stops 50% (iv) maximum use of rapid transit--50%, (v) least walking distance--60%. In addition, 80% of the systems provide information on connection points and 70% provide information about transit vehicle location. In terms of a map base, only one uses Etak, five use Tiger, and four use other map bases. Only 10% of the systems provide advance ticketing and reservation capability.

In-Terminal Traveler Information Systems

Thirty five percent of the suppliers have in-terminal information systems (7/20). The suppliers include: Tidewater Inc, Westinghouse, Etak Inc, Megadyne Information Systems, Teleride Sage Ltd, Peek Traffic, and Midwest Electronic Industries. Of the available systems, six disseminate information by dot matrix displays (6/7), four use flipover displays, four use liquid crystal displays (LCD), two use TV monitors, five use synthesized voice messages, two use interactive audio terminals, three use interactive video terminals with keypads, and four use interactive video terminals with touch sensitive screens.

In terms of disseminating information, 86% (6/7) provide schedule/departure times (50% historical and 50% in real time), 71% provide multimodal itinerary information (50% historical and 50% in real time), 42% provide trip chaining information (itinerary optimization) (50% historical and 50% in real time), 42% provide rideshare opportunities information (50% historical and 50% real time). The systems can provide best route information based on traveler selected criteria, which include: (i) shortest time--42% (60% historical and 40% real time), (ii) lowest fare--(42%), (iii) intermediate stops 28% (iv) maximum use of rapid transit--42%, (v) least walking distance--42%. All available systems provide information on connection points, 86% provide information on transit vehicle location, 7 1% provide information on delays, and all provide information on the destination. Only one of the available systems uses Etak as the map base, 60% use Tiger and 30% use other map bases. None provide advanced ticketing and reservation and all available systems can be linked to other sources of information.

In-Vehicle Traveler Information Systems

Thirty percent of the companies have in-vehicle information systems (6/20). They include: AEG Westinghouse, Motorola, Etak Inc, Megadyne Info Systems, Peek Traffic, and Midwest Electronic Industries. Among the available systems, five use synthesized voice messages to disseminate information (5/6), five use dot matrix displays, three use video displays, two use flap displays, and two use other technologies. In terms of information provided to travelers, 83% give schedule information (5/6) (40% historical and 60% in real time), 66% provide the expected arrival time at the next stop (25% historical and 75% in real time), 50% provide waiting times at connecting points (25% historical and 75% in real time), 66% provide connecting services (16% historical and 83% real time), 83% provide destination information, 16% provide seating availability information and 66% provide next stop announcements. Only one of the available systems uses Etak as the map base, 32% use Tiger and 50% use other map bases. None provide advance ticketing and reservation.

Rideshare Matching Software

Twenty five percent of the suppliers provide real-time rideshare matching software (5/20). They include: Tidewater Inc, Comsis, Megadyne Information Systems, Fone Link Inc, and Commuter Transportation Services. A majority (60%, 3/5) provide real-time matching and 80% use Tiger as their map base (4/5). Forty percent of the latest systems match passengers by grid (2/5), 40% match by zip code, 20% also match by other methods.

Automatic Vehicle Identification

Twenty six percent of the suppliers have AVI technologies (6/20 companies). They are: Amtech Technologies, EMX Inc, AEG Westinghouse, Fone Link Inc, LazerData, and Peek

Traffic. Among the available technologies, two are based on Infrared/Optical, three on Radio Frequency (RF)/Microwave, two on Inductive Loop, and one on Surface Acoustic Wave (SAW). Sixty six percent have 2 way communication capability between reader unit and vehicle mounted transponder (4/6), and 16% encode variable data (1/6). In terms of technology performance, 20% of the respondents claimed that their systems miss no vehicles (1/5) and 80% miss less than 1% of the vehicles.

Automatic Vehicle Location

Fifty percent of the suppliers sell AVL systems (10/20 companies). They are: EMX Inc, AEG Westinghouse, Motorola, Etak Inc, Qualcomm Inc, Megadyne Information Systems, Rockwell RR Electronics, II Morrow Inc, Teleride Sage Ltd, and Peek Traffic. Of the systems on the market, only one uses dead reckoning (1/10), two use dead reckoning with map matching, four use GPS with dead reckoning, two use GPS with map matching, two use Proximity Beacon Sign Post, (all of which use "sharp" transmissions [localized signals] as opposed to "broad" transmissions [long range signals]), four use Radio Determination (60% of which use Loran-C), five use Satellite Based systems (80% of which are GPS/NAVSTAR), and five systems use other methods.

In terms of technology performance, 20% (2/10) of the companies' latest system track the location of the transit vehicle within 30 feet, 60% track between 30 and 100 feet, 10% track between 100 and 500 feet, and 10% track more than 500 feet. Fifty percent of the systems update location information every 1 second (4/8), 12.5% update every 30 seconds, 25% update every 1 minute, and 12.5% update every hour.

Collision Avoidance Systems

Only two companies have collision avoidance systems. They are: Westinghouse and Rockwell RR Electronics. None provide warning only. Both provide warning and braking functions.

On-Board Computers

Thirty five percent of the vendors have on-board computers (7/20). They include: Westinghouse, Etak Inc, Qualcomm Inc, Pulse Electronics, Rockwell RR Electronics, II Morrow Inc, and Peek Traffic. They collect data on speedometers--83% (5/6), and ignition status (on/off)--66%. A majority of the systems (86%) are connected to a central computer for data gathering and processing (6/7). Only one system each uses Etak and Tiger as the map base and the remaining five use other map bases.

Transit Operations Software

Fifteen percent suppliers provide transit operations software (3/20). They include: Westinghouse, Megadyne Information Systems, and Teleride Sage Ltd. None of the available systems provide marketing functions; only one provides management and administration functions; one provides network and operations planning based on historical and real time information; and two provide vehicle and crew scheduling. Sixty six percent use Tiger as the map base (2/3) and 33% use other map bases. Sixty six percent of the latest transit operations software is connected to an Automatic Vehicle Location system (2/3) and 66% is connected to Automatic Vehicle Identification systems.

Electronic Ticketing Systems

Ten percent of the companies supply ETS (2/20). They are Schlumberger and AEG Westinghouse. Both systems collect origin destination data and revenue information disaggregated by route and ticket type; one collects passenger information disaggregated by class, route, and time of day. In terms of payment, one system can accept credit cards; both have tickets that can be reused by adding fare to them; one has tickets good for 1 ride only; both have tickets good for a limited number of rides, whereas one has tickets good for unlimited rides. Moreover, one of the ETS has tickets that the traveler can use for multimodal transportation.

Automatic Passenger Counter

Fifteen percent of the suppliers have APCs (3/20). They are: Westinghouse, Red Pine Instruments, and Peek Traffic. One company uses a pressure-sensitive mat for counting, and the rest use infrared beams. All use random access memory (RAM) to store information. A majority (66%) send passenger counts at bus stops to the dispatcher in real time (2/3). One company reported that their system misses less than 1% of passengers, and provides information on the total number of passengers served along a route, the actual number of passengers on the bus, and the number of passengers boarding and alighting at certain stops.

Automatic Demand-Responsive Dispatching Systems

Thirty percent of the suppliers have automatic demand responsive dispatching systems (6/20). All provide scheduling functions, (66% are based on historical data and 33% on real time data), all provide dispatching (66% based on historical data and 33% on real time data), 50% provide billing functions, 83% provide service monitoring and reporting (33% based on historical data and 66% on real time data. About 66% of the latest systems consider traveler preferences (4/6), 83% provide transit vehicle location information to the traveler in real time, 66% provide best route information according to traveler selected criteria, 33% have advance reservations capabilities, 83% can respond to immediate requests and all can respond to standing orders. Two of the systems use Tiger as the map base and the remaining three use other map bases.

Other Transit Technologies

Through the brochures, some other transit technologies were identified. Table 4.5 provides a summary of technology type, their capabilities and functions and suppliers.

Table 4.5 Other technologies available from responding suppliers.

Technology Supplier	Technology Type	Technology Capabilities/Functions
Burle Industries	*Sliding Gate Operator	*Designed for industrial and commercial slide gate operator requirements
	*Swinging Gate Operator	*Designed for industrial and commercial swing gate applications
	•Slide Gate	•For pedestrian traffic entrances where handicappped provisions may be required
	*Waist-High Swing Gate	*Rugged, for use in supermarkets, drug stores, stadiums, etc
	*Security Turnstile	•For superior strength and reliability. Especially for fence-line applications
	*Waist-High Turnstile	*Ruggedly designed turnstile used wherever pedestrian control is desired
Luminator	*LCD: MAX Destination signals for rail vehicles	*LCD signs explicitly for mass transit: -wide viewing angle - high contrast ratio - flexibility for future expansion of railway system
Megadyne Information Systems	*Electronic Map	*Provides updatable digitized map. Generates a geocoded database. Retrieval time is .05 seconds. Uses a set of retrieval qualifiers that make a given location unique.
AEG Westinghouse	*AC Propulsion System	*Offers most advanced AC technology available today
Cubic Corporation	•MARTA gate	*Turnstile type; accepts coins, tokens, magnetically encoded passes
	*Encoder/Sorter	*Used to encode header on new tickets or sort previously used tickets by category
	*Treadle Doctor	*Treadle contact interface that provides treadle information to alert maintenance and toll auditors of impeding treadle contact problems before they impact accountability.

Table 4.5 (continued) Other technologies available from responding suppliers.

Technology Supplier	Technology	Technology Capabilities/Functions
Cubic, contd	*Patron Toll Display	*Dot matrix type, provides variable messages within view of patrons
	•Overhead Classification Indicator	*Provides the supervisor with a visual indication of the collector's vehicle classification information
	*Island Traffic Light	*Mounted at the exit end of the toll lane
Pulse Electronics	•TrainLink II Locomotive Cab Unit	*Across board compatibility, cost effective retrofit, clear displays, emergency function
	•TrainLink II End of Train Unit	*Transmits key information to engineer and provides emergency braking capability; lightweight; upgradable; various models

DISCUSSION

The results show that several advanced transit technology products are on the market. These commercially available new technologies provide opportunities for improving transit system performance and facilitating the use of transit systems. The trend in new technologies is toward transfer of data in real-time through electronic media. A majority of the new transit technologies have the capability to support either traveler decisions or transit operator decisions (or both).

In the field of advanced transit technologies, some relatively large companies, such as Schlumberger, Westinghouse, Motorola and Rockwell, have entered the market. Smaller companies are also competing, however, they seem more fluid--a significant portion of the companies we contacted had gone out of business. Based on the data, the larger companies did not seem to focus on specific products or technology areas, however it is observed that certain products, such as collision avoidance systems and electronic ticketing systems, are supplied only by the larger companies.

The evaluation of technologies showed that certain products may be more promising from the perspective of transit operators while others from the perspective of transit operators. The implication for technology testing is that a well balanced set of operator- and traveler-based technologies should be selected.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

A method for classifying advanced transit technologies according to their impacts was developed. They can be classified as “smart traveler” and “smart operator” technologies. The structure was used to explore commercial availability of new transit technologies. In addition, the structure could also be used to evaluate the impacts of new transit technologies during field operational tests.

Survey research showed that technology suppliers have several products which are likely to vary in their benefits to transit operators and travelers. The opinions provided by technology suppliers provide some insights into technology benefits. For example, the AVL system is rated highly on improving monitoring as well as controlling transit headways while information technologies are rated highly on traveler impacts, i.e., they will increase traveler comfort and satisfaction.

Before field testing, a strategy should be designed to select appropriate technologies. One approach is to select a well balanced set of operator- and traveler-based technologies. This translates into testing at least some traveler information systems. It is possible that pre-trip transit information systems (including real-time rideshare systems) may have greater potential. This is because during the pre-trip stage travelers have greater flexibility in travel choices and also because such systems are expected to have significant impacts on traveler behavior. At least some operator-based technologies should also be tested. Automatic Vehicle Monitoring Systems may be good candidates because they are likely to have significant transit operator impacts and the information obtained on transit system performance can also help travelers.

The technology selection process should consider using various technologies jointly. Specifically, the organization and attributes of various technologies may be critical in determining their impacts. For example, the joint implementation of traveler information systems and automatic vehicle monitoring systems may enhance their individual benefits (compared with implementing them separately). Specifically, the information collected through vehicle monitoring may be used to improve transit operations as well as provide real-time information on transit system performance. Overall, interaction effects of technologies may be significant and need to be explored.

The following structure is proposed for evaluating new technologies in an APTS testbed:

1. Develop selection criteria for technologies.

- Performance, capabilities and functions of new technologies.
- Extent and nature of impacts on transit operations and travelers.
- Interaction of various technologies if jointly implemented.
- Mix of operator- traveler-based technologies
- Compatibility of the new technology with the existing transit system.
- Funding and financing opportunities for technology testing and deployment.

2. Select candidate technologies for field testing.
3. Design the experiment and develop methodology.
4. Select transit system for testing technology according to criteria.
5. Conduct pre-experiment analysis.
6. Test in the context of the Advanced Transportation Systems testbed.
7. Systematically evaluate impacts in terms of measures of performance.

- Conduct traveler behavior and operator performance surveys.
- Collect and analyze transit system performance and traveler information system data before and *after* implementation.

8. Outcomes of field experiments.

- Impacts of advanced transit technologies on transit operations and travelers
- Improvements in design and performance of specific technologies and implementation decisions.

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APPENDIX 1

UNIVERSITY OF CALIFORNL4, BERKELEY

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

Institute of Transportation Studies

Partners for Advanced Transit and Highways (PATH)
Richmond Field Station
1301 South 46th Street, Bldg 452
Richmond, CA 94804
TEL: (510) 231-9495 FAX: (510) 231-9565

Oct 20, 1992

Dear Technology Developer:

The California Department of Transportation (Caltrans) is planning for the deployment of advanced transit technologies. As described in the enclosed California Public Transportation Systems (CAPTS) plan, Caltrans' program is exploring the latest transit technologies, such as your own.

It is our objective to evaluate candidate transit technologies for public demonstration and testing in the Bay Area. We need your cooperation. Prior to November 15, please send us:

(1) Literature describing your technologies and products.
(2) Completed questionnaire (enclosed).

Note that not all questionnaire sections may apply to you. All responses will be strictly confidential.

Thank you for your time. If you have any questions please contact me or Hisham Noeimi at (5 10) 642-9208.

Sincerely,

Asad Jan Khattak

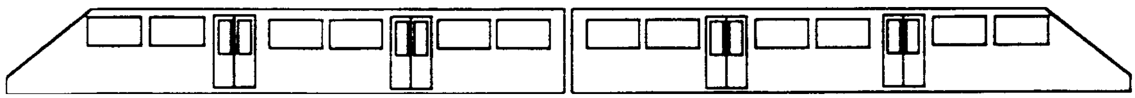
Dr. Asad Khattak
Research Engineer

SURVEY OF ADVANCED TRANSIT TECHNOLOGIES

CALIFORNIA PATH

Manufacturer ______________________________

Please **answer only the sections that apply to you.**



Q1. Do you sell Automatic Vehicle Identification (AVI) systems?

Cl **Yes** (please continue) ❑ **No** (skip to Q2)

i. What is your latest AVI system based on?

❑ Infrared/Optical
❑ Radio Frequency (RF)/Microwave
❑ Inductive loop
❑ Surface Acoustic Wave (SAW)

ii. Does your latest AVI system have two-way communication between the reader unit and the vehicle mounted transponder?

❑ *Yes* ❑ *No*

iii. Does your latest AVI system encode variable data (e.g. passenger counts)?

❑ ✡♏⬧ ❑ ☠□

iv. On the average, what percentage of the vehicles does your system miss?

❑ Does not miss at all
❑ Misses between 1 and 5%
❑ Misses more than 10%
❑ Misses less than 1%
❑ Misses between 6 and 10%

Q2. Do you sell Automatic Vehicle Location (AVL) systems?

❑ ✡♏⬧ (please continue) ❑ ☠□ (skip to Q3)

i. What method does your latest AVL system use in tracking the vehicle? (please check one only. If your system uses a combination of methods not listed below please write the combination under Other)

❑ Dead reckoning
❑ Dead reckoning with map matching
❑ GPS with dead reckoning
❑ GPS with map matching
❑ Proximity beacon/sign post → O Sharp transmissions (localized signals)
0 Broad transmissions (long-range signals)

❑ Radio determination → O Certain radio frequencies
O Loran-C
O Omega
O Other (please specify) ____________

❑ Satellite-based AVL systems ——— O GPS/NAVSTAR
O TRANSIT
0 Other (please specify) ____________

❑ Other (please specify) ____________

ii. How accurately can your latest system track location of a transit vehicle?

❑ Between 30 and 100 ft.
❑ More than 500 ft.
❑ Between 100 and 500 ft.
❑ Other (please specify) ______ ft.

iii. How often does your latest system update location information? (please specify) ______ seconds

Q3. Do you sell Automatic Passenger Counter (APC) systems ?

• I Yes (please continue) ☐ No (skip to Q4)

i. What counting device does your latest system use?

Cl Pressure-sensitive mat
☐ Infrared beams
☐ Multi switch treadle mat
☐ Other (please specify)______________

ii. What does your latest system use to store the information?

☐ Random access memory (RAM)
☐ Magnetic tape
☐ Compact disk (CD-ROM)
☐ Other (please specify)______________

iii. Can your latest system send passenger counts at bus stops to the dispatcher in real-time?

☐ *Yes* ☐ *No*

iv. On the average, what percentage of passengers does your system miss?

☐ Does not miss at ail
☐ Misses less than 1%
☐ Misses between 1% and 5%
☐ Misses between 6 and 10%
☐ Misses more than 10%

v. Can your latest APC system provide the following information?

	Yes	**No**
a Total number of passengers served along certain route.	☐	☐
b. Actual number of passengers on the bus.	☐	☐
c. Number of passengers boarding and alighting the vehicle at certain stops.	☐	☐

Q4. **Do you sell electronic ticketing systems?**

Cl Yes (please continue) ☐ No (skip to Q5)

i. What information does your latest system collect? (check all that apply)

☐ Origin-destination data
☐ Revenue information disaggregated by ——— ○ Route ○ Ticket type

☐ Passenger information disaggregated by ———→ ○ Class ○ Route ○ Tie of day

Cl Other (please specify) ______________________

ii. Does your system accept credit cards (e.g. Visa, Master Card) for trip payment?

☐ ✡♏⬧ ☐ No

iii. Can your tickets be reused by adding fare to them?

☐ *Yes* ☐ No

iv. Are your tickets good for

	Yes	*No*
a. One ride only?	☐	☐
b. Limited number of rides?	☐	☐
c. Unlimited rides?	☐	☐

v. Can the traveler use your tickets for multi-modal transportation? (e.g. bus & subway)

☐ ✡♏⬧ ☐ No

QS. Do you sell pre-trip information systems'?

❑ Yes (please continue) ❑ **No** (skip to Q6)

i. What kind of technology does your latest pre-trip information system use? (check all that apply)

❑ Automatic dial phone
❑ Telephone to computer operator
❑ Telephone & voice recognition
Cl Computer & modem
• 7 Teletext
❑ Videotext
❑ Cable TV
❑ Other (please specify)________________

ii. Does your latest system provide the following information to the traveler.7

	Yes	No	→ If yes, is the information historical or real-time? Historical	Real-time
a. Schedule/departure times	❑	❑	→ O	O
b. Multi-modal itinerary	❑	❑	→ O	O
c. Trip chaining (itinerary optimization)	❑	❑	→ O	O
d. Ride share opportunities	❑	❑	→ O	O
e. Best route based on traveler-selected criteria:				
- Shortest time	❑	❑	→ O	0
- Lowest fare	❑	❑		
- Intermediate stops	❑	❑		
- Maximum use of rapid transit	❑	❑		
- Least walking distance	❑	❑		
- Other (please specify) ____________				
f. Connection points	❑	❑		
g. Transit vehicle location	❑	❑		

i. Other (please specify and indicate if the information is historical or real-time)

____

____

iii. What does your pre-trip information software use as a platform?
(e. g. IBM uses PC as a platform)

________________ (please specify platform)

iv. What type of operating system does your pre-trip information software use ?
(e. g. MS-DOS)

________________ (please specify operating system1

v. What is the map base of your pre-trip information software?

❑ Etak ❑ Tiger ❑ Navtek ❑ Other (please specify) ________________

vi. Does your latest pre-trip information system provide advance ticketing and reservation?

❑ *Yes* ❑ No

Q6. Do you sell in-terminal traveler information systems?

☐ **Yes** (please continue) ☐ **No** (skip to Q7)

i. How does your latest in-terminal information system disseminate information? (check all that apply)

☐ Dot matrix displays
☐ Flipover displays
☐ Liquid crystal displays (LCD)
☐ TV monitors
☐ Synthesized voice messages
☐ Interactive audio terminals
☐ Interactive video terminals with keypads
☐ Interactive video terminals with touch-sensitive screens
☐ Other (please specify) ____________

ii. Does your latest system provide the following information to the traveler?

	Yes	No	If yes, is the information historical or real-time? Historical	Real-time
a. Schedule/departure times	☐	☐	O	O
b. Multi-modal itinerary	☐	☐	O	O
c. Trip chaining (itinerary optimization)	☐	☐	O	O
d. Ride share opportunities	☐	☐	O	O
e. Best route based on traveler-selected criteria:				
- Shortest time	☐	☐	O	O
- Lowest fare	☐	☐		
- Intermediate stops	☐	☐		
- Maximum use of rapid transit	☐	☐		
- Least walking distance	☐	■		
- Other (please specify) ________				
f. Connection points	☐	☐		
g. Transit vehicle location	☐	☐		
h. Delays information	☐	☐		
i. Destination	☐	☐		

j. Other (please specify and indicate if the information is historical or real-time)

____

iii. What does your in-terminal information software use as a platform?
(e. g. IBM uses PC as a platform) ____________ (please specify platform)

iv. What type of operating system does your in-terminal information software use?
(e. g. MS-DOS) ____________ (please specify operating system)

v. What is the map base of your in-terminal information software?

☐ Etak ☐ Tiger ☐ Navtek ☐ Other (please specify) ____________

vi. Does your latest in-terminal information system provide advance ticketing and reservation?

☐ *Yes* ☐ No

vii. Can your latest in-terminal information system be linked to other sources of information ?

☐ Yes ☐ No

Q7. Do you sell in-vehicle traveler information systems?

☐ Yes (please continue) ☐ No (skip to Q8)

i. What kind of technology does your in-vehicle information system use to disseminate information?

☐ Synthesized voice messages
☐ Dot matrix displays
☐ Video displays
☐ Flap displays
☐ Other (please *specify)* ________________

ii. Does your latest system provide the following information to the traveler?

	Yes	No	If yes, is the information historical or real-time? Historical	Real-time
a. Schedule	☐	☐	O	O
b. Expected arrival time at next stop	☐	☐	O	O
c. Waiting times at connecting points	☐	☐	O	O
d. Connecting services	☐	☐	O	O
e. Destination	☐	☐		
f. Seating availability	☐	☐		
g. Next stop announcements	☐	☐		

h. Other (please specify and indicate if the information is historical or real-time) ________________

____

iii. What does your in-vehicle information software use as a platform?
(e. g. IBM uses PC as a platform) ________________
(please specify platform)

iv. What type of operating system does your in-vehicle information software use?
(e. g. MS-DOS) ________________
(please specify operating system)

v. What is the map base of your in-vehicle information software?

☐ Etak ☐ Tiger ☐ Navtek ☐ Other (please specify) ________________

vi. Does your latest in-vehicle information system provide advance ticketing and reservation?

☐ Yes ☐ No

Q8. Do you sell automated demand-responsive dispatching systems?

Cl **Yes** (please continue) ☐ **No** (skip to Q9)

i. What functions does your latest system provide?

		Historical	Real-Time
☐	Scheduling	O	0
☐	Dispatching	O	O
☐	Billing	O	O
☐	Service monitoring & reporting	O	O

ii. Does vour lutest automated demand-responsive dispatching system:

	Yes	No
*a. Consider traveler preferences? (e. g. type **of** vehicle)*	☐	☐
b. Provide transit vehicle locution information to the traveler in real-rime?	☐	cl
c. Provide best route according to traveler-selected criteria?	☐	☐
d. Provide advance reservations?	☐	♍●
e Respond to immediate requests?	☐	☐
f. Respond to standing orders?	☐	☐

iii. What does your automated dispatching sojiware use as a platform?
(e. g. IBM uses PC as a platform)

____
(please specify platform)

iv. What type of operating system does your automated dispatching software use?
(e. g. MS-DOS)

____
(please specify operating system)

v. What is the map base of your automated dispatching software?

☐ Etak ☐ Tiger ☐ Navtek ☐ Other (please specify) ____________________

Q9. Do you sell transit operations software?

☐ **Yes** (please continue) ☐ **No** (skip to Q10)

i. Whatfunctions does your latest system provide?

		Historical	Real-Time
☐ Marketing			
☐ Management & administration			
☐ Network & operations planning __________	is the information provided	0	0
Cl Vehicle & crew scheduling __________	IS the information provided	O	0
☐ Other (please specify) ____________________			

ii. What does your transit operations software use as a platform?
(e. g. IBM uses PC as a platform)

____
(please specify platform)

iii. What type of operating system does your transit operations sojiware use?
(e. g. MS-DOS)

____
(please specify operating system:

iv. What is the map base of your transit operations sojiware?

☐ Etak ☐ Tiger ☐ Navtek ☐ Other (please specify) ____________________

v. Is your latest transit operations software connected to:

	Yes	No
a. Automatic Vehicle Location (AVL) system	☐	☐
b. Automatic Vehicle Identification (AVI) system	☐	☐
c. Other (please specify) ____________________		

Q10. Do you sell On-Board Computers (OBCs)?

❑ Yes (please continue) ❑ No (skip to Q11)

i. What data does your latest system collect? (check all that apply)

Cl Speedometer data Cl Ignition status (on/off) ❑ Other (please specify) ________

ii. Is your latest OBC connected to a central computer for data gathering and processing?

❑ ✡♏♦ ☝● No

iii. What does your OBC software use as a platform?
(e. g. IBM uses PC as a platform) ________ (please specify platform)

iv. What type of operating system does your OBC software use?
(e. g. MS-DOS) ________ (please specify operating system)

v. What is the map base of your OBC information software?

❑ Etak ❑ Tiger ❑ Navtek ❑ Other (please specify) ________

Q11. Do you sell collision avoidance systems ?

Cl Yes (please continue) ❑ **No** (skip to Q12)

i. Does your latest software provide

	Yes	*No*
- warning only?	❑	❑
- warning & braking?	❑	❑
- braking only?	❑	❑

Q12. Do you sell ride-share matching software?

❑ ✡♏♦ (please continue) ❑ ☠❑ (skip to Q13)

i. Does your latest software provide real-time (immediate) matching?

❑ *Yes* ❑ No

iii. What does your ride-share matching software use as a platform?
(e. g. IBM uses PC as a platform) ________ (please specify platform)

iv. What type of operating system does your ride-share matching software use?
(e. g. MS-DOS) ________ (please specify operating system)

v. What is the map base of your ride-share matching software?

❑ Etak ❑ Tiger Cl Navtek ❑ Other (please specify) ________

vi. How does your latest system match passengers? (check all that apply)

❑ ✌⚐ ♑❏♓♎ ❑ By zip code

❑ Other (please specify) ________

Q13. Please list all other traveler information technologies that you supply.

____

____

Q14. Please answer the following questions about your main (largest revenue) transit technology.

i. What category does your technology belong to? (please check one only)

- ☐ Automatic Vehicle Identification (AVI)
- ☐ Automatic Vehicle Location (AVL)
- ☐ On-Board Computer (OBC)
- ☐ Automated demand responsive dispatching system
- ☐ Collision avoidance system
- ☐ Automatic passenger counter (APC)
- ☐ Pre-trip information system
- ☐ In-terminal traveler information system
- ☐ In-vehicle traveler information system
- ☐ Ride-share matching software
- ☐ Transit operation software
- ☐ Electronic ticketing system
- ☐ Other (please specify) ____________

ii. Please describe characteristics of your "typical customer" (i. e. transit agency to whom you supplied this technology).

	Lower end	Average	Upper end
a. Fleet size (number of vehicles)			
b. Number of transit drivers			
c. Annual operating costs $			
d. Total route miles served			
e. Number of registered vanpools (if the technology you supply is a ride-share matching software)			

iii. What is the typical reduction in the following operating cost of your typical customer due to implementation of this technology? (please express the reduction as percentage)

a. Maintenance cost reduced by ____________%
b. Fuel cost reduced by ____________%
c. Wages reduced by ____________%
d. Management cost reduced by ____________%
e. Other (please specify) ____________

iv. How much did this technology increase ridership?

- ☐ No change
- ☐ More than 0% but less than 1%
- ☐ More than 1% but less than 2%
- ☐ More than 2% but less than 3%
- ☐ More than 3% (please specify if possible)

v. *Please check the box that best describes your opinion regarding the main transit product.*

a. *Improved ability of operator to monitor driver performance*
❑ strongly agree ❑ agree ❑ neutral ❑ disagree ❑ strongly disagree ❑ don't know

b. *Improved ability to control transit headways*
❑ strongly agree ❑ agree Cl neutral ❑ disagree ❑ strongly disagree El don't know

c. *Reduced labor hours required to operate rhe transit system*
Cl strongly agree Cl agree ❑ neutral ❑ disagree Cl strongly disagree ❑ don't know

d. *Reduced time required to perform transit operations*
❑ strongly agree ❑ agree ❑ neutral ❑ disagree ❑ strongly disagree ❑ don't know

e. *Reduced human errors (e. g. calculation errors) for transit operators*
❑ strongly agree ❑ agree ❑ neutral ❑ disagree ❑ strongly disagree ❑ don't know

f. *improved security for transit users*
❑ strongly agree Cl agree ❑ neutral ❑ disagree ❑ strongly disagree ❑ don't know

g. *Reduced the number of user complaints*
❑ strongly agree ❑ agree • 1 neutral ❑ disagree ❑ strongly disagree Cl don't know

h. *Improved accident safety for users*
Cl strongly agree ❑ agree ❑ neutral ❑ disagree ❑ strongly disagree ❑ don't know

i. *Increased flexibility of travel choices*
❑ strongly agree ❑ agree ❑ neutral ❑ disagree ❑ strongly disagree Cl don't know

j. *Made transit easier to use*
❑ strongly agree ❑ agree ❑ neutral ❑ disagree ❑ strongly disagree ❑ don't know

k. *Improved travel comfort*
❑ strongly agree ❑ agree ❑ neutral ❑ disagree ❑ strongly disagree ❑ don't know

1. *Improved user satisfaction with the transit service*
❑ strongly agree ❑ agree ❑ neutral Cl disagree ❑ strongly disagree ❑ don't know

vi. *What is the price range for your technology?*

I- Purchase & installation $ ____________
2- Additional annual fees $ ____________

vii. *What is the status of your technology?*
Cl Proposed ❑ Prototype ❑ In-service
Cl Experimental ❑ Pilot

viii. *Please tell us how you may improve this technology* ____________
____
____

Q15. Please answer the following questions about your second main transit technology.

i. What category does your technology belong to? (please check one only)

- ❑ Automatic Vehicle Identification (AVI)
- ❑ Automatic Vehicle Location (AVL)
- ❑ On-Board Computer (OBC)
- ❑ Automated demand responsive dispatching system
- ❑ Collision avoidance system
- ❑ Automatic passenger counter (APC)
- Cl Pre-trip information system
- ❑ In-terminal traveler information system
- ❑ In-vehicle traveler information system
- ❑ Ride-share matching software
- ❑ Transit operation software
- ❑ Electronic ticketing system
- ❑ Other (please specify) ____________

ii. Please describe characteristics of your "typical customer" (i. e. transit agency to whom you supplied this technology).

	Lower end	Average	Upper end
a. Fleet size (number of vehicles)			
b. Number of transit drivers			
c. Annual operating costs $			
d. Total route miles served			
e. Number of registered vanpools (if the technology you supply is a ride-share matching software)			

iii. What is the typical reduction in the following operating cost of your typical customer due to implementation of this technology? (please express the reduction as percentage)

a. Maintenance cost reduced by ____________%
b. Fuel cost reduced by ____________%
c. Wages reduced by ____________%
d. Management cost reduced by ____________%
e. Other (please specify) ____________

iv. How much did this technology increase ridership?

- ❑ No change
- ❑ More than 0% but less than 1%
- ❑ More than 1% but less than 2%
- ❑ More than 2% but less than 3%
- ❑ More than 3% (please specify if possible)-

v. Please check the box that best describes your opinion regarding your second main transit product.

a. improved ability of operator to monitor driver performance

☐ strongly agree ☐ agree ☐ neutral ☐ disagree ☐ strongly disagree ☐ don't know

b. Improved ability to control transit headways

☐ strongly agree ☐ agree Cl neutral ☐ disagree ☐ strongly disagree Cl don't know

c. Reduced labor hours required to operate the transit system

Cl strongly agree ☐ agree Cl neutral ☐ disagree Cl strongly disagree ☐ don't know

d. Reduced time required to perform transit operations

☐ strongly agree ☐ agree ☐ neutral ☐ disagree ☐ strongly disagree ☐ don't know

e. Reduced human errors (e. g. calculation errors} for transit operators

☐ strongly agree ☐ agree ☐ neutral • 7 disagree ☐ strongly disagree ☐ don't know

f. Improved security for transit users

Cl strongly agree ☐ agree ☐ neutral ☐ disagree ☐ strongly disagree ☐ don't know

g. Reduced the number of user complaints

☐ strongly agree Cl agree Cl neutral El disagree ☐ strongly disagree ☐ don't know

h. Improved accident safety for users

☐ strongly agree Cl agree ☐ neutral ☐ disagree ☐ strongly disagree ☐ don't know

i. Increased flexibility of travel choices

☐ strongly agree ☐ agree ☐ neutral ☐ disagree ☐ strongly disagree ☐ don't know

j. Made transit easier to use

☐ strongly agree Cl agree Cl neutral ☐ disagree ☐ strongly disagree ☐ don't know

k. Improved travel comfort

☐ strongly agree ☐ agree ☐ neutral Cl disagree ☐ strongly disagree ☐ don't know

1. Improved user satisfaction with the transit service

El strongly agree ☐ agree ☐ neutral ☐ disagree ☐ strongly disagree Cl don't know

vi. What is the price range for your technology?

1- Purchase & installation $ ____________________

2- Additional annual fees $ ____________________

vii. What is the status of your technology?

☐ Proposed ☐ Prototype ☐ In-service

☐ Experimental ☐ Pilot

viii. Please tell us how you may improve this technology ____

____

____

Q16. How many years have you been in business? ______ (number of years)

Q17. How many full-time employees do you have? ______ (number of employees)

Q 18. How many employees are engineers/programmers? ______ (number of engineers/programmers)

Q19. Are your products manufactured in the US? ☐ Yes ☐ No (Skip to Q21)

Q20. Do you have an office in California? ☐ Yes ☐ No

Q21. Do you fabricate any of your products in house? ☐ Yes ☐ No

If yes, please list all products manufactured in house ______

______

Q22. Please list all transit agencies that you have supplied with any of your technologies.

Transit agency	Technology

Comments (optional) ______

______

______

______

______

______

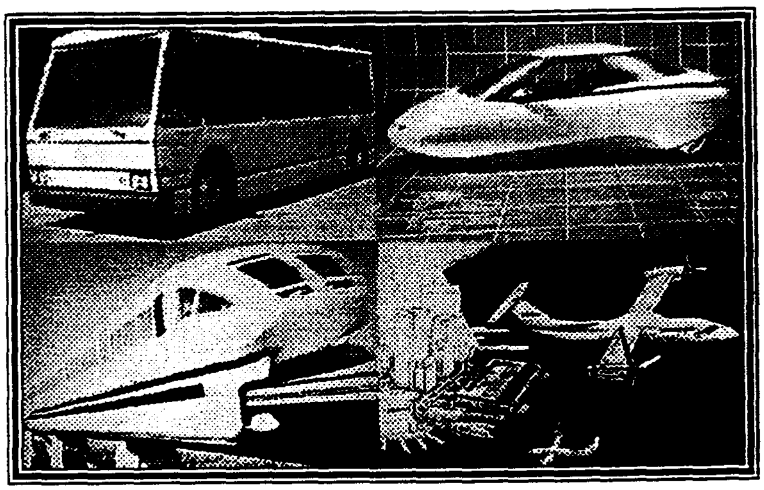
Thank you for your help. Please send both the completed questionnaire and literature describing your technologies and products prior to October 7 to the following address:

Dr. Asad Khattak/Dr. Haitham Al-Deek
UNIVERSITY OF CALIFORNIA
Institute of Transportation Studies
109 McLaughlin Hall
Berkeley, CA 94720
USA

APPENDIX 2

CALIFORNIA ADVANCED PUBLIC TRANSPORTATION SYSTEMS (CAPTS)

Research and Development (R&D) Plan



California Department of Transportation (Caltrans)
Division of New Technology, Materials and Research
Off ice of Advanced Transportation
Management and Information Systems
Advanced Public Transportation Systems Branch

Introduction

In 1986, the California Department of Transportation (Caltrans) and the University of California jointly initiated a program for the research and development of advanced technologies with application to transportation, including transit, paratransit and ridesharing. This effort started with a project to develop roadway electrification for a Santa Barbara electric bus system and has grown rapidly to a robust, multimodal program with international recognition - now known as Partners for Advanced Transit and Highways (PATH).

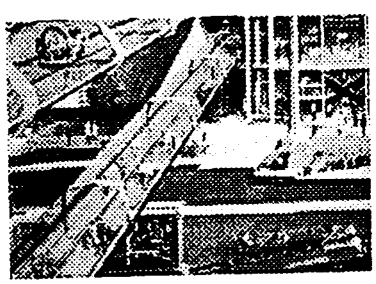
To further expand technology efforts in the transit, paratransit and rideshare areas, Caltrans and PATH have developed this California Advanced Public Transportation Systems research and development (R&D) plan.

Problem Definition

The transportation sector today is comprised of relatively unconnected systems and modes which are all too often out of balance with mobility needs. This lack of balance and "connectivity", together with an almost exclusive reliance on petroleum as a fuel source, has contributed to the transportation-related problems of traffic congestion and accidents, energy dependency and air pollution which threaten our country's continued economic well-being.

Recognizing this underutilization of existing transportation facilities and equipment, the U.S. Congress recently passed the "Intermodal Surface Transportation Efficiency Act of 1991". This act proposes to "develop a National Intermodal Transportation System consisting of all forms of transportation in a unified, interconnected manner, including the transportation systems of the future".

Advanced Public Transportation Systems (AM'S): An Overview



Transportation officials have long strived for an intermodal surface transportation system. Historically, technological and institutional barriers have prohibited its development. It now appears that continuing advances in computing, telecommunications, and other electronic technologies may soon overcome the technology barriers. Caltrans and PATH have established a parallel effort within its technology program to recognize and eliminate institutional barriers as they become identified.

The air transport system may be the best example of technology's promise for surface transportation, whether bus, truck, automobile or rail. Even with its shortcomings, this system does an impressive job of using its available resources in balancing supply and demand. This is achievable because the pilot, aircraft and traffic control infrastructure form one integrated system. The integration, in turn, is enabled by the use of "smart" technologies that link these individual elements, provide each with accurate condition information in real-time, and assist in the optimization of aircraft and system operations given those conditions.

The "Intelligent Vehicle-Highway System" (IVHS) is a core concept of advanced technology application to surface transportation. IVHS envisions the use of "smart" technologies to provide the linking and system optimization seen in the air transport system. And as with the air system, the performance of the vehicle operator, vehicle and roadway can also be individually enhanced.

The analogy between air transport and IVHS goes beyond the system component level and into the user/service provider realm. With computer and communication advances, the airlines have been able to use sophisticated and flexible fare structures that tailor prices to maximize use of available capacity. Some airlines give customers direct access to flight information and let them make their own reservation through videotex services. These same technologies can be applied to surface transportation, greatly increasing the availability of public transportation service information, expanding transit service options including customized services with customized fare structures, and even making "real-time" ridesharing feasible.

Two principal goals in applying IVHS technologies to transit, paratransit and rideshare vehicles will be to improve individual system operations and to enhance connectivity across systems (and modes). Operational improvements brought about by the implementation of IVHS technologies can greatly increase both the productivity and the attractiveness of travel by these high occupancy options. This will encourage travelers to use these modes instead of single-occupant automobiles, mitigating demand on the highway network and improving the efficiency of the intermodal transportation system.

The Federal Transit Administration has developed an Advanced Public Transportation Systems program as a component of an overall U.S. Department of Transportation initiative in IVHS. The program is structured to undertake research and development of innovative applications of advanced transportation technologies that most benefit public transportation and increase its competitiveness in the transportation marketplace.

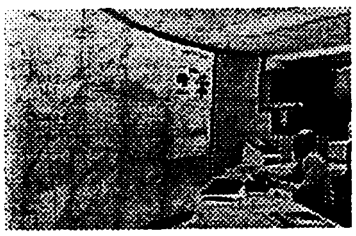
Caltrans has established a parallel R&D program for IVHS technologies applicable to transit, paratransit and rideshare. The California Advanced Public Transportation Systems (CAPTS) program encompasses four "families" of technologies: Advanced Traveler Information Systems, Advanced Transportation Management Systems, Fleet Management and Control Systems and Automated Vehicle Control Systems.

Advanced Traveler Information Systems (ATIS)

ATIS provide travelers both with appropriate and timely data to improve their travel decision making and transactional services necessary to implement their decisions. These services can be provided to homes, offices, schools, and to vehicles via telephone, radio, TV, computers, roadway signing, in-vehicle devices and other means. When delivered to an in-vehicle display, ATE can also provide the driver with dynamic route guidance.

Potential ATIS applications include pre-trip planning, real-time rideshare matching, in-terminal and in-vehicle information systems, multimodal trip reservation systems, integrated billing systems and "mobility manager" systems.

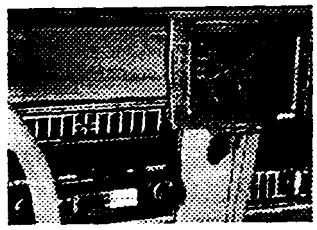
Advanced Transportation Management Systems (ATMS)



ATMS optimize and coordinate freeway and signalized street operations with public transportation system operations, balancing demand with system capacity and conditions. Such systems can facilitate more comprehensive transit and high occupancy vehicle priority strategies while maintaining overall network performance.

ATMS applications include optimized traffic signals, traffic signal preemption, adaptive traffic control, transportation operation systems, and high occupancy vehicle (HOV) verification /enforcement.

Fleet Management and Control Systems (FMCS)



FMCS incorporate a range of technologies that can improve the productivity, safety and regulation of transit, paratransit and rideshare vehicles.

Potential applications include transit operations software, integrated fare media, electronic ticketing and automated tip payment systems, automatic vehicles identification, location and monitoring, paratransit dispatching systems, and "smart bus" systems.

Automated Vehicle Control Systems (AVCS)

AVCS technologies give transit, paratransit and rideshare drivers enhanced capabilities using electronics to support or perform driving functions.

AVCS applications include obstacle detection and collision avoidance, automatic steering (lateral control), automatic headway (longitudinal control), automated guideways, and automated highway systems.

Since 1986, PATH has built the foundations of a working partnership with a broad range of public and private interests.

Caltrans now intends to use this plan to team with public and private sector partners to demonstrate and evaluate California Advanced Public Transportation Systems which will allow local and regional governments to combine publicly-operated and privately-operated transit, paratransit and ridesharing services into an integrated public transportation **system.**

For more information on the CAPTS research and development plan, please contact:

Robert Ratcliff
Research Manager
(916) 323-2644
Caltrans Office of Advanced Transportation Management and Information Systems

APPENDIX 3

TECHNOLOGY SUPPLIERS RESPONDING TO SURVEY

CADMOS PRO+
MICRO DYNAMICS CORPORATION
Attn. Paul D. Buroker
2207 E. Morgan Avenue - Suite J
Evansville, Indiana 477 1 l-4355

TEL: (812) 477-3090

LUMINATOR
A MARK IV INDUSTRIES CO
I.V.H.S. Division
Attn. Paul Manuel
6020 Ambler Dr
Mississauga, Ontario
Canada L4W 2P1

TEL: (416) 624-3025
FAX: (416) 624-4572

SIEMENS PLESSEY CONTROLS LTD
Attn. Ian C. Day
Soopers Lane, Poole,
Dorset, BH17 7ER
ENGLAND

TEL: (0202) 782000
FAX: (0202) 78233 1

RED PINE INSTRUMENTS LTD.
RR # 1
Denbigh, Ontario KOH 1LO

TEL: (613) 333-2776

II MORROW INC.
Att. Karl Poley
2345 Turner Rd. S.E.
P.O. Box 13549
Salem, OR 97309

TEL: (503) 581-8101
FAX: (503) 364-2138

MEGADYNE INFORMATION SYSTEMS
Att. Marketing Manager
2800 28th Street, #205
Santa Monica, CA 90405

TEL: 310-452-1677

MGM MIDWEST ELECTRONIC INDUSTRIES INC
Att. Larry Chmiel
4945 W.Belmont Avenue
Chicago IL 60641

TEL:3 12-685-3500

SCHLUMBERGER TECHNOLOGIES
Att. Bertrand Moritz
825 B. Green Brier Circle
Chesapeake, Virginia 23320

TEL: (804) 523-2178

TIDEWATER CONSULTANTS, Inc.
Att. J.C. Barenti
160 Newton Road, 4th Floor
Virginia Beach, Virginia 23462

TEL: (804) 497-8951 (J.C. Barenti)

AMTECH CORP.
Att. Marketing Manager
17304 Preston Rd Bld E 100
Dallas, TX 75252

TEL: (214) 520 9600

VAPOR CANADA INC.
Att. Kelly Gravelle
10655 Henri Bourassa West
Montreal, Quebec H4S1A1
CANADA

TEL (514) 335-4214

EMX, INC.
Att. Joe Rozgonyi
3570 Warresville Center Road
Shaker Heights, OH 44122

TEL: 2 16-464-2980

LAZERDATA
Att. Marketing Manager
2400 Diversifield Way
Orlando, FL 32804

TEL:407-843-8975

ETAK
Att. Marketing Manager
1455 Adams Drive
Menio Park, CA 94025

QUALCOM
Att. Marketing Manager
10555 Sorento Vallay Road
San Diego, CA 92121

TEL:619-587-1121

COMMUTER TRANSPORTATION SERVICES
Att. Marketing Manager
3550 Wilshire Boulevard, #3300
Los Angeles, CA 90010

COMSIS
Att. Marketing Manager
2275 Swallow Hill Road
Bldg 500, Suite # 3
Pittsburgh, PA 15220

FONE LINK INC
Att. Marketing Manager
P.O. Box 1188
Newport Beach, CA 92659

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